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ABSTRACT

The purposes of the project described in this report were to train curriculum specialists and to develop and test curriculum design training materials. The first phase of the project included the development of training materials and their use to train a small group of students. During the training of the pilot group of students, an effective design model was identified and a format developed for self-instructional materials. The design was a structured-curriculum model supplemented with additional elements and procedures suitable for complex subject matter, called the process model for individualization of curricular (PIC). This model became the bases for design of the curriculum course, and the PIC procedures were taught as a design model. This phase of the project ended with a revision of the materials based on the experiences and results encountered with the students. The second phase of the project was a series of field tests of the materials and their revision based on formative evaluation procedures. (Author/MLF)

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CURRICULUM DESIGN AND DEVELOPMENT PROJECT

FINAL REPORT - Federal Project 0-9043-B
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Volume I

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CURRICULUM DESIGN AND DEVELOPMENT PROJECT

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CURRICULUM DESIGN AND DEVELOPMENT PROJECT

Introduction

The Curriculum Design and Development Project, conducted by the Learning Research and Development Center at the University of Pittsburgh in cooperation with the Department of Curriculum and Supervision at the University, had two purposes: to train curriculum specialists and to develop and test curriculum design training materials. There has been a shortage of personnel trained in the highly specialized procedures which have sprung from the emerging field of instructional technology. Most research and development centers and regional laboratories, therefore, have had to provide on-the-job training for staff members of curriculum development projects. In addition, there is a need to disseminate to teachers and administrators training materials which can help them to evaluate and select or develop their own individualized instructional materials.

This project was planned in two phases. The first phase would include the development of training materials and their use to train a small group of students, who would also take other courses at the University, would serve internships on curriculum projects, would write dissertations on curriculum-related topics and would receive doctorates from the Department of Curriculum and Supervision of the School of Education, University of Pittsburgh. The major part of their training in curriculum would come from the materials the project would design and develop. This phase of the project would end with a revision of the materials based on the experiences and results encountered with the pilot group of students. The second phase of the project would be a series of field tests of the materials and their revision based on formative evaluation procedures.

The intensive pilot testing effort was carried out during 1971 - 72. Phase two of the project, the series of field tests, extended from the Fall of 1972 to December, 1973, involving over one hundred students. The activity of these two phases is presented in the following report.

PROGRAM DEVELOPMENT: PHASE 1

The Training

The Curriculum Design and Development Project, in it initial phase, trained the pilot group of students while the training materials were being developed, so that the most effective methods, strategies, procedures and materials could be incorporated in the final product. The pilot students worked intensively for two terms with the Project staff, providing extensive feedback on the instructional materials, which underwent almost continuous revision.

The original curriculum design course included an appreciable amount of class discussion, a number of guest lectures, readings and worksheets, field trips, individual and group research projects and one-to-one interaction with the course instructors. While each of these activities seemed to provide useful insight or experience in some phase of curriculum design, the students requested more self-instructional materials.

A change to a more completely self-instructional format would make the program product better suited to dissemination. At the same time, to accommodate to students with different backgrounds and different requirements there was a need to organize the instruction and to provide diagnostic testing for maximum flexibility in selecting objectives and progressing through the program.

During the training of the pilot group of students, an effective design model was identified and a format developed to meet these needs. The design model was a structured-curriculum model, as described by Lindvall and Cox (1969), supplemented with additional elements and procedures suitable for complex subject matter, called the process model for individualization of curricula (PIC). (See Appendix A.) This model became the basis for design of the curriculum course and the PIC procedures were taught as a design model.

Each unit of the self-instructional materials includes a rationale for selection of the unit objectives and their relation to the rest of the course; a listing of the terminal and prerequisite objectives; and a charted hierarchy of the unit objectives, graphically demonstrating their interrelationships. One or more study guides incorporate tasks, which serve as curriculum embedded items to help the student monitor his progress. Reading sources are listed for each task and are coded to the unit objectives. Each unit includes an overview; articles from journals and Learning Research and Development Center publications; a bibliography; a posttest and answer keys. (See course materials and The Training Product).

This first phase of the program proved to be an efficient way of developing training materials and, simultaneously, providing intensive training for a small group of students. Without the students it would not have been possible to produce proven training materials expeditiously. At the same time, the concentrated training proved highly effective. This training has been evaluated by case studies of the original four doctoral students. These studies are elaborated here and in Appendices C and D.

The Pilot Students

The pilot students who are now completing their work for the doctorate from the Department of Curriculum and Supervision of The School of Education, University of Pittsburgh, came to the program with no curriculum experience. Diane Davis had been a substitute secondary school teacher. Her B.A. was in psychology from Youngstown State University, Youngstown, Ohio.

Nicholas Laudato had completed undergraduate work at Carnegie-Mellon University in May, 1971. His B.S. was in mathematics.

Unlike the other students, Sister Claire McCormick had a extensive background in education. She had been Dean of Studies and Assistant Principal at St. Pius School, Atlanta, Georgia. Previously, she had been Principal of Notre Dame Academy, Villanova, Pennsylvania and a teacher of English and Latin. Her B.A. was in music from Trinity College, Washington, D.C., and her M.A. in education administration from Catholic University.

Tommye Whiting had been Educational Coordinator for Job Opportunities for Youth in Houston, Texas, and previously a junior high school history teacher. Her B.A. was in French from Oberlin College, Oberlin, Ohio.

Another student, Larry Hubka, did not continue for the doctorate, but did receive a master's degree in curriculum and supervision, was a teacher and coordinator of distributive education.

The students are probably the best indication of the effectiveness of the materials. They are judged, by the professionals with whom they have worked at the University of Pittsburgh, and particularly at the Learning Research and Development Center, as thoroughly competent specialists in curriculum design. (See Appendix C, The Students, and Appendix D, Sample Student Work.)

Diane Davis spent her internship with the External Studies Program at the University of Pittsburgh, working with University professors helping them to individualize their courses and make them self-instructional so they could be offered extra-murally to students who could not readily come to the campus. Nicholas Laudato worked as an intern in the Computer-Assisted Instruction Project and Sister Claire McCormick worked with the New Reading System (NRS Project). Both of these are projects of the Learning Research and Development Center at the University of Pittsburgh. Tommye Whiting worked on an exploratory project in social studies in the third grade at Frick School, a Pittsburgh public school which is a developmental school of the LRDC.

Dissertation topics of the students are related to their internship experiences. A self-concept instrument for cultural-minority children grew out of Tommye Whiting's internship in an inner city school, working on development of lessons in the concept of social interaction. Sister Claire McCormick is analyzing the NRS Reading Program of the LRDC to identify the instructional strategies it uses and to formulate principles and generalizations for the teaching of reading. Nicholas Laudato is developing a program for teaching children to solve word problems by computer without computation. Diane Davis is developing a model for evaluation and is evaluating some of the curricula being individualized and externalized, for the University of Pittsburgh's External Studies Program.

In addition to their curriculum course work, which is represented by the twelve units which accompany this report, their other courses at the University, their internships and their doctoral research, each of these students has used his training to assist educators in the field. Diane Davis conducted some research in the schools with Dr. James Holland, University of Pittsburgh, Associate Professor of Psychology and Research

Associate of the LRDC. Nicholas Laudato worked out a behavior modification program for a Hebrew School director who had discipline problems. Tommye Whiting worked as a consultant on individualization at the schools in Freedom, Pennsylvania. She consulted with the Braddock, Pennsylvania School District teachers who were attempting to quiet racial unrest stemming from recent integration in the district. She worked, also, with social workers for the Pittsburgh Board of Education.

All four of the students assisted in conducting a day-long workshop for the Babcock (Pa.) School District. The R&D Project Director observed their interaction with the teachers and administrators and evaluated it. Clearly, each of these students can use his training effectively himself and can, also, teach others.

PROGRAM DEVELOPMENT: PHASE 2

Field Testing

Phase two began with a second test of the materials (first field test), conducted with twenty-three students, during the Fall and Winter trimesters of 1972 - 73. The course was offered by the University's Department of Curriculum and Supervision, through the External Studies Program of the School of General Studies. The students, post-baccalaureate adults who could not readily attend on-campus courses, came to the campus only three times: for pretests, postests and interaction sessions. This externalized feature made it necessary to strengthen the course's self-instructional characteristics.

The course materials proved effective and suitable to the very diverse needs of these students. All but two students successfully completed the first trimester. Fourteen of these students enrolled in the second trimester of the course and completed it with eleven A and three B grades. (See Summative Evaluation, p. 17 for more evaluation data.) Flexibility in rate of progress was provided by use of a G (incomplete) grade for students who needed more time to master the objectives. These G grades are removed when the student's curriculum projects have been completed and evaluated. (A description of the projects of field test students is in Appendix E.)

The third test of the materials (second field test), began during the Winter Term of 1973. It was conducted by an instructor who had not been involved in the R&D Training Program, with sixteen students, who completed the first trimester satisfactorily. Only three of this group of students continued the course for a second trimester, in the Fall of 1973, and all earned A grades in the course.

Sixty students took part in the fourth and final test of the materials from September to December, 1973. Most of them have successfully completed four units. Many of them have indicated their intention to continue through the entire instructional sequence, now consisting of twelve units.

Two new units were added to the External Studies course before the final field test, replacing materials used in the pilot program on the background to instructional design. The University's Department of Curriculum and Supervision offered the highly flexible option of taking all twelve units externally for nine graduate credits or any four of the units for three credits.

In addition to testing the two new units, the final field test also was an opportunity to try out the option of choosing freely those units needed by the student. This was found feasible and useful for some students. In addition, the appropriate posttest items for each student's unique combination of units were quickly located by the coding system used to identify units, objectives, levels and test items. They were then administered by the University Testing Center to those students who could not conveniently come to the interaction session.

The total number of students who took part in the pilot and field tests of these materials was one hundred and three. The range of students in the field tests, their educational background and their needs, has been extremely broad. One student did not have a college degree. She had been trained as a practical nurse in a program for minorities. A few students had no previous graduate credits, but most students had graduate credits ranging from a few to several credits beyond the Master's degree, and there have been four post-doctoral students enrolled. The majority of the students have been teachers. There have been, also, guidance counsellors, reading specialists, community college instructors or assistant professors, registered nurses, a director of a nursing school, and industrial training directors. Several graduate students in Curriculum and Supervision and Educational Communications also have taken the course.

FORMATIVE EVALUATION

Formative evaluation of these materials was accomplished by use of unit rating sheets, which provided data for revision, and posttests for each unit, which gave evidence of the degree to which the materials successfully taught the concepts and skills necessary to accomplish unit objectives.

The most extensive alteration in the course materials occurred during the pilot test when the course content and format underwent major changes. However, the two revisions of the materials as a result of the field tests were largely the result of feedback from the students. (See Appendix B, this volume, for applicable data.) In addition to unit rating sheets and unit posttests, students were given mailers on which they could list a question and receive a response from the instructor. Few of these were used but the questions that were returned also suggested portions of the materials which required fuller explanations.

Not all students in the External Studies field tests returned the unit rating sheets and the responses of those who did were not consistent. Some students had problems understanding the articles which other students rated most valuable. Yet, it was possible to identify and correct weaknesses in the materials or to make use of specific suggestions for improvement. The External Studies staff compiled data for each of the ten units on subject matter relevancy, clarity of objectives, sufficiency of materials, interest of readings, effectiveness of self-scored tests, exercises and study guides. (See Appendix B, this volume, for this data.)

It was interesting to note the difference in unit ratings under different instructors. The comments revealed an even greater difference in student opinion of the instructional materials then did the numerical ratings. Also, 18 of 23 students of instructor one continued into the second trimester while only 3 students out of 16 continued from the class of instructor two.

Since the course is self instructional and is meant to be readily disseminable it was important to find out why this difference occurred. With only three interaction sessions a trimester, two of which were given over largely to testing, the student/instructor interaction could not have caused this difference.

Analysis of the student posttests revealed a rather dramatic difference in amount and type of feedback. Instructor number one, whose students reported an overwhelmingly positive reaction to the units wrote extensive comments on every posttest. Instructor number two wrote relatively few comments.

There was also a clear difference in the type of feedback. Instructor two usually gave feedback in the form of questions or in a negative form. For example, "This is not backward chaining", but without explaining what it was or giving an example of the principle the student was attempting. Sometimes there was a simple comment, "Use can mean apply," but no explanation to clear up the student's confusion about how apply differs from analyze or synthesize. One student used both the terms, deductive and inquiry, in describing a lesson. The comment made by the instructor was, "Are these compatible?"

Instructor number one, on the other hand, responded to a hierarchy that was not charted correctly by doing one or more possible alternative hierarchies and suggesting the student consider them. In response to an objective requiring the student to "demonstrate awareness of the instructional strategies on which the program is based," the question was not only "By doing what?" An example was given, as well, "by defining the rationale for each."

An objective for in-service training was stated as follows: "Teachers, upon completion of the in-service program, are to perform in the role of facilitator in the new environment." Teacher number one responded. "This is too vague. The role of facilitator should be defined in terms of what the teacher will do. Example: ----in the role of facilitator as shown by continuous roving, reinforcing of process behaviors, suggesting how students can take responsibility for finding data, encouraging peer tutoring, etc."

An objective terminating a sequence on government functions stated that the student should be able to "apply these ideas specifically to the U.S." The student's objective was qualified by the instructor with the addition of "by describing how the government is organized and operates to perform these functions." Frequently Instructor number one suggested readings in the student's own field or specified the review necessary. She also commented favorably on every point it was possible to praise.

As a result of this experience in field testing the materials, it was apparent that the instructor's manual must stress feedback and must emphasize the confusions which can result for students attempting self-instruction for the first time.

Self-instructional materials have great possibilities for freeing professors to do research or to work with students on a one-to-one basis while the rest of the class is working independently. They offer an opportunity for people who live at a distance from a university to continue their education without lengthy commuting. A single course can be made flexible and adaptive enough to meet the needs of a broad range of students, to whose differences a professor lecturing in a classroom would not be able to adapt the instruction. However, the amount of feedback which might be acceptable when students and instructor are meeting each week is totally insufficient when the student cannot readily ask questions and receive answers.

The feedback should be as positive as possible. When something is clearly wrong, it must be labelled wrong, of course, but the correct response must be given. If, as in this course, there are many neither right nor wrong responses, an improvement in quality can be encouraged by suggesting several alternative responses: "Why not try this?" "Would this be better, perhaps?" Whenever possible, each posttest should result in an individualized prescription for further reading, review, rewriting.

The unit rating sheets, including student comments on what they liked best and least, were extremely helpful in eliminating unsuccessful articles. Some articles students found to be difficult were retained because they were the best available for a particular purpose. Often, students reread them later and changed their minds about their value. Some students failed to realize, in spite of being told, that they were to select the readings they needed to master the objectives. The Manual alerts the instructor to this student tendency. It was at the suggestion of several students, also, that a glossary was added to the course materials.

The students evaluated the usefulness of the various sections of the course format, but this data was only obtained from the group of students who took both trimesters of the course in the Fall and Winter of 1972-73. They found the Overviews the most useful portion of the units. The terminal objectives were rated next, then the hierarchy. Prerequisite and study guide objectives were third in value. Posttests, rationale, and tasks and sources were fourth with the same number of students finding them "very useful." Those students who did not rate all of the sections mentioned here as "very useful" rated them "useful", except for one or two students who rated each one "somewhat useful". The element of unit format which was adjudged of least value (3 very useful, 1 useful, 5 somewhat useful and 3 not too use ful) was the bibliography. However, for students who needed additional help it was mentioned as indispensable.

Use of the pretests to diagnose student needs was helpful for students who intended to study the entire sequence as well as those who wanted to work in only a few specified units. Particularly for adult students who have not been in school for awhile, but for all students studying self-instructional materials, it is not helpful to receive a pretest score. It was found that listing of the possible number correct and the number missed in each of the levels also was not useful. The pretest was used primarily for self-placement and for a student not familiar with diagnostic testing it was painful to learn that most of the questions had not been answered correctly, even though that was the expected outcome.

The procedure finally used was a note to each student indicating the areas in which he seemed to be knowledgeable and those in which he should concentrate his efforts.

It was found that students come to the program strongest in terminology, the reform movement, instructional theory and behavioral objectives. They are weakest in hierarchies, taxonomies, discipline elements, learning theory and criterion referenced testing.

For the field test of the second half of the course the posttest for the first half was used to diagnose student deficiencies (if any) and to write a letter containing an individualized prescription for making up the deficiencies before continuing with the next unit. Each error in the posttest was recognized, not by indicating the student had made an incorrect response, but by a list headed "Notes on Posttest." Each note was a statement of a concept, principle, generalization or method corresponding, correctly, to the student's erroneous response. The individualized prescription might be to reread an overview, practice a behavior demanded in a unit posttest, review specified articles or read additional suggested materials in the student's own field.

Feedback directly from the students in the form of unit rating sheets and indirectly from their pretests and unit posttests were used for formative evaluation of the curriculum program. It resulted in the addition of two units on the background to instructional design because several students expressed a need for such an introduction to the course. It resulted in an Instructor's Manual to suggest supplementary activities and to alert the instructor to those directions to which students often fail to attend. The Manual also explains some of the instructional strategies used in the design of the materials.

Formative evaluation of the curriculum materials led to elimination of some articles, substitution of others, changing of some tasks or rewording of some posttests. It led to placing answer keys at the end of the unit rather than after each study guide, to extensive use of feedback, and to the addition of two units and an Instructor's Manual.

SUMMATIVE EVALUATION

The point made by Lindvall and Cox (1970, p. 58), in their monograph on the IPI program evaluation, applies equally to this program which is also based on a structured-curriculum model: "With this approach to program development there is really no summative evaluation. There is only summative evaluation for a given stage, describing what results are produced by the program at that stage." The results of the program as of its terminal date, November 30, 1973 are described here. Each new group of students expands the potential impact of the program, as each past group of students has provided formative evaluation data leading to program improvement. A product-oriented curriculum in which mastery is measured by ability to produce comprehensive instructional systems can only be evaluated by the quality of the products produced and the growth of the students from neophytes in curriculum to designers and developers of effective curricular components.

The pretests, as noted in the chapter on Formative Evaluation, were used for diagnosis. Nevertheless, it is possible to measure the growth between pre and posttest with the first group of field test students who continued through the ten units then included in the program. For this group of students, the pretest was scored and the range was 23 to 42, the median 41. The posttest range was 74 to 96 with a median of 91. Not included were the three lowest-score students (46,60,70), who elected to take incomplete grades, continued to work with the materials, and completed them with two A's and one B in the following trimester.

Validity of posttests in criterion-referenced measurement depends on whether or not they test the objectives. The unit posttests in this course are valid because they all demand the same behavior that is demanded by the unit terminal objective.

In a structured curriculum, the student must master the objectives of one unit before he can proceed to the next. When the student is working independently and, in some cases, checks even his own posttest, progression is determined by him. However, the instructor checks enough of the posttests to monitor student progress and to prescribe progression to a new unit or more work in the present unit.

Test evidence has shown that pilot and field test students could perform the following behaviors:

I.* Analyze the structured-curriculum model in terms of adaptability to the needs and goals of a fast-changing world.

II. Given an educational problem, identify theoretical formulations which could be used to select appropriate instructional strategies or to design instructional systems.

III. Given a content scope and sequence for a one semester course, identify elements of the discipline structure.

III. Given elements of discipline structure and content scope and sequence, select content instances.

IV. Given a terminal objective construct a behavioral hierarchy and code each component objective by the appropriate Bloom, Krathwohl or Gagne level.

V. Given a student population and behavioral objectives, or self-selected population and objectives, specify appropriate instructional methods, media, strategies and classroom environment.

VI. Given evaluation problems, be able to describe how the curriculum designer would solve them.

*Objectives are numbered by unit.

VII. Given hypothetical administrative problems, prescribe, on the basis of administrative theory, the most effective means of solving them.

VII. Given an innovative curriculum, plan an in-service training program to teach teachers to implement it.

VIII. Draw up and specify in writing his own tentative, step-bystep procedures for the design of instruction, which may be specific to his own area of instruction and which will be used for his own design project.

XI. Do curriculum content, concept and component analyses and chart and code his behavioral hierarchy by Bloom and Krathwohl or Gagne's levels.

X. Given a curriculum hierarchy (or a student-generated hierarchy) select the optimal testing points and write appropriate tests.

XI. Given (or self-selected) lesson objectives, CET test and student characteristics; the student should be able to identify an appropriate method, strategies, classroom environment and alternative media, fill out a lesson writer's rationale and write a lesson.

XII. Given a description of a management problem, solve it.

XII. Given an individualized structured curriculum of his own design, design a complete management system.

In addition to what the students of the program are able to do, the program may be further evaluated in terms of the five products which were promised in the December, 1972 Report of the Project (p. 5)

1. Personnel with specialized training in curriculum design.

   The listing of what the students trained in the program can do specifically on the preceding pages indicates that this promise has been fulfilled. In addition, Appendix D exhibits work of the pilot group of students. This includes a paper on the External Studies Delivery System by Diane Davis; a paper on Computer Assisted Instruction in Problem Solving: The Word Problem by Nicholas

Laudato; an Analysis of NRS, the LRDC Reading Program by Sister Claire McCormick; and a series of cartoons to teach social interaction skills by Tommye Whiting. These four curriculum students evaluate their training in Appendix C.

2. A tested training program and guides for conducting instruction in the program.

   The Curriculum Design Project has developed twelve self-instructional units, with pre and post-tests and an Instructor's Manual. This comprises a comprehensive course in the design of structured, adaptive, individualized curricula, and the management systems, administration and in-service training to implement them. It has been tested as described above. The four volume course accompanies this Report.

3. An operational model for a consortium of training agencies.

   In the Curriculum Design Project most of the cooperation was between the Learning Research and Development Center and the University of Pittsburgh School of Education, particularly the Department of Curriculum and Supervision. This program would not have been possible without the cooperation and the willingness to try innovative approaches to training shown by the Curriculum and Supervision Department. This cooperation resulted in highly flexible, highly individualized courses of study for the graduate students enrolled in the program.

4. Tested approaches for evaluating training programs both on a program development basis as well as a student basis.

   The Unit Rating Sheets have proven an effective way to evaluate curriculum training materials (Appendix B). Use of the structured model, behavioral hierarchies and criterion-referenced tests makes possible straight-forward evaluation of student products to measure attainment of program goals. The terminal objective of each unit hierarchy can be posttested.

Tasks, which include questions to direct student attention and aid retention, serve as curriculum embedded test items to help the student monitor his own progress. These have proven very effective.

5. The final outcome of the operational test (the 1972 report suggested) may be contributions to theory and research on the development of training programs.

The curriculum project has hinted at several interesting principles of individualized, self-instructional curriculum design which should be further investigated by other researchers:

1. It has long been argued, particularly in response to critics of too much testing, that testing and teaching begin to merge in IPI and other structured curricula. The format developed for this program virtually merges curriculum embedded tests with teaching sequences in the tasks which are the instruction. The optimal arrangement of input (reading) and practice (answering questions or performing tasks) for adult learners should be investigated.

2. The field tests seem to indicate that for a self-instructional course addressed to adults and curriculum product-oriented, positive and specific feedback, with examples, is essential. For students who are highly motivated and self-directive it is possible to use the course without feedback from an instructor. The principle seems to be that self instructional training for development of curriculum products demands extensive

feedback to be optimally effective.

3. Pretests, used diagnostically to indicate which units can be selected if the student needs only some but not all twelve of the units, seem to provide the student with the greatest amount of direction if they are reported in terms of what the student knows and what he needs to know. Reporting of scores is not helpful. Reporting of number correct out of the possible number is not helpful. Both discourage the student learning independently.

4. For self-instructional materials, it is a very useful procedure to divide (and code) tests into units and, within units into taxonomic levels. This makes it possible to report in a meaningful way to the student in terms of his weaknesses and strengths. It is helpful to a student who is managing his own instruction to tell him he needs to work on methodology or on application of curriculum design principles to a given problem or, perhaps, evaluation of curricular components in terms of external criteria.

The Curriculum Design Program is unique in its comprehensiveness. It delves into all phases of an individualized instructional system. It is readily transportable. Portions of it have been used at Governor's State University by a former colleague of the project director and by department members in the Department of Curriculum and Supervision at the University of Pittsburgh.

Student attitudes are overwhelmingly positive. Laudato (Appendix C) praises its efficiency, "After attaining a more global picture, beginning again in detail was most instructive. In retrospect, the manner in which knowledge and skills were slowly built upon one another was remarkably efficient."

Product impact can be judged from the quality of the curricula being produced by the students (see Appendix E), by the impact on the students, several of whom are continuing their graduate studies because of the interest aroused by the course; and by the number of students to whom other departments at this university (and other universities) are recommending the course. From a first field test of twenty-three students in the Fall of 1972, the number enrolled in the Fall of 1973 rose to 60. In addition, two students of the course, one from the pilot group and one from the field test group, are working with university professors for the External Studies Program helping them to individualize and externalize their courses following the course design model. This is providing students who could not otherwise get to the University with carefully structured courses of quality at least equal to those offered on campus.

THE TRAINING PRODUCT

The curriculum design and development course and instructor's manual described in this report consists of twelve self-instructional units divided into three major concentrations. (Course outlines, Appendix A) The first section, which was left out of the first field test but was found to be necessary for many students, is on the Background to Instructional Design. Under the Goals of Education are study guides on Goal Setting; The Reform Movement and Individualization of Instruction. This examines forces influencing educational goals and provides historical perspective on instructional innovations of the past two decades.

The second unit is on the Psychological Bases of Instruction which includes study guides on Learning Theories, Instructional Theories and Behavior Management. Here the major theories about how people learn and how we can help them to learn are described and compared, not to convert this very specialized course into a survey of the psychology of learning and instruction, but to establish the framework upon which the Theoretical Rationale for Instructional Design, the succeeding section, is built.

The Theoretical Rationale for Instructional Design helps the student to understand why a structured curriculum design is based on the conceptual structure of a discipline; the purpose of stating objectives in terms of observable behavior; and the need for explicit selection and recording of the instructional strategies used to move the student from his entering to the desired terminal behavior. The kinds of evaluation used in designing and developing individualized instruction and the rationale for them follows. The concluding unit describes the differences in administration required for an adaptive instructional environment and the kinds of in-service training needed for its staff. The procedures for designing and developing each of these components are described and supported in theory in the study guides: Structure of the Discipline, Content and Concept Analysis, Behavioral Objectives, Taxonomies, Component Analysis, Adapting Instruction to Learner Characteristics, Instructional Methods, Media and Strategies, Classroom Environment, Formative and Summative Evaluation in Curriculum Design, Administration and In-Service Training.

The final section of the curriculum course is Applied Instructional Design. Beginning with Design Procedures and ending with Management System Design, this portion of the course requires that the student design components of a curriculum on the structured curriculum model for individualization of instruction. The units between the design unit and the management system unit are Specification of Objectives and Structuring of Hierarchies, Criterion-Referenced Test Construction and Lesson Writing.

The student plans his own design procedures with the option of altering them as he proceeds, if they prove to be ineffective or inefficient. The study guides in this unit are Application of Instructional Theory to Instructional Design and A Process Model for Instructional Design, which is the design model on which the course is written. (See Appendix A)

Other study guides in this section are Identifying and Writing Objectives, Structuring and Charting Hierarchies, Writing Test Items, Sampling the Objective Domain and Assembling Tests, Selection of Instructional Methods, Media and Strategies, Constructing a Lesson Rationale and Writing a Lesson, Feedback System and Staff Planning. Procedures for each of these curriculum design steps are detailed and are practiced by the students. Instructional strategies are not prescribed. The decisions which need to be made in designing instruction adaptive to individual needs, and the points at which they must be made, are clearly explained. The presently available options, within the limits of the knowledge we have about how we can help people learn, are set forth for the student to examine.

Each unit in the curriculum course begins with a rationale which establishes the relationship of the unit objectives to the overall course objectives. The terminal objectives follow, stated in behavioral terms, and indicate the explicit behaviors which each student is expected to be able to exhibit at the completion of the unit. These terminal objectives are followed by prerequisite objectives to the unit.

A charted hierarchy of all the objectives of the unit gives the student a graphic representation of the structural relationship between the objectives and makes it possible for him to find out, at a glance, how far he has progressed and what remains to be achieved.

The lesson materials are in the form of study guides, two or three to a unit. Each study guide represents a branch of the instructional sequence and begins with objectives. These lesson objectives are further defined in terms of tasks that are similar to curriculum embedded items for the student to perform. They help the student to evaluate his own progress. They also are designed to assure the student's attention and direct it to the important information he should retain. Each task is listed parallel to a source which may be an article from a journal incorporated in the unit, a chapter in one of the four prescribed texts, or a portion of the unit overview. The sources are coded to the objectives they help the student to master. At the end of the unit, an answer key is provided for each study guide so the student can receive immediate feedback on his responses. The tasks may require the application of skills previously learned in the course to given design problems, the analysis of elements of given curricula, or synthesis in designing curriculum components.

The unit overview follows the study guides, giving an abbreviated version of unit content and usually including explanations and descriptions of concepts and procedures not readily or briefly available in books or articles.

Each unit has a bibliography with items also coded to the objectives to make it possible for the student to locate additional references to assist him in mastering any given unit objective.

Finally, at the end of each unit is a posttest which may include an answer key, criteria or examples of appropriate responses that would indicate mastery of unit objectives. This unit test not only provides information to instructor and student on his progress and governs his decision to go on to a new unit, but also provides evidence of the effectiveness of the materials.

This course differs from most curriculum training programs in that it is based on a process model for curriculum design (PIC) which is concept-centered and which includes procedures for a separate concept analysis, as well as content and component analysis steps in design procedures. Also, the model calls for application of research-based instructional strategies to instructional design and record-keeping to monitor their effectiveness. Finally, the model demands systematic sampling of higher level skills of analysis and synthesis in each unit of instruction.

Most of the procedures taught in the course are derived from experiences of research and development centers and the new field of instructional psychology.

While this is based on a specific procedural model for instructional design, it is in no way limited in the variety of theories from which the designer can borrow, or the creative approaches to instruction which it is possible to employ in building on the model structure.

The entire course has been revised on the basis of the feedback from pilot and field testing. An Instructor's Manual has been written to identify some of the misunderstandings which could arise when students are studying independently and to suggest how the instructor can prevent problems by his own directions and the kind of feedback he provides on the student's work. The Manual also suggests supplementary activities.

There is a pretest for the entire course which is coded according to skill levels and units so that it is possible to pretest on any unit or group of units or the entire course. It is also possible to pretest on particular skills: for example, curriculum analysis.

This product is twelve highly adaptive, highly flexible, self-instructional units in curriculum design and development, a course pretest, unit posttests and an instructor's manual.

Potential users of the course are R & D Centers for staff training, In-Service Teacher Training Institutes, University Undergraduate Schools of Education, University Extra-Mural Post-Baccalaureate Programs (See Appendix E for the broad range of students this course has served), Graduate Education Programs for Curriculum Specialist, for Master's Degree or for Doctorate in Curriculum.

A Publisher's Alert and a Request for Proposals have been sent to The National Institute for Education.

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Appendix A

PIC: A Process Model for the Individualization of Curricula

(The Design Model)

PIC: A PROCESS MODEL FOR THE INDIVIDUALIZATION OF CURRICULA

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PIC: A PROCESS MODEL FOR INDIVIDUALIZATION OF CURRICULA

Doris T. Gow

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INTRODUCTION

The Carnegie Commission on Higher Education (1972) has predicted that "off-campus instruction of adults may become both the most rapidly expanding and the most rapidly changing segment of post secondary education (p.4)." Because there are few self-instructional materials capable of meeting this need, they have urged that learning technology centers be established to engage in design, planning and production of instructional units for use by participating institutions and extra mural educational systems (pp. 55-56).

This paper describes a model used to develop and package curriculum design training materials and University of Pittsburgh External Studies courses. It suggests that the model would be effective and efficient for the production of the instructional units proposed by the Carnegie Commission. The training materials themselves would be appropriate to train personnel for the learning technology centers the Commission has advocated.

Called PIC or the Process Model for the Individualization of Curricula, the model combines structured curriculum design components with procedures for developing curricula which emphasize the structure of the discipline. These procedures focus on process by sampling in each unit all skill levels in order to promote the building of independent learning capabilities; systematic application of research-based instructional strategies to the design of instruction; and use of independent inquiry within a structured model for instruction.

EVOLUTION OF THE MODEL

This curriculum model was developed at the Learning Research and Development Center at the University of Pittsburgh to provide curriculum design training materials and to train curriculum design specialists. The training was federally funded to help alleviate the well-documented shortage of trained personnel for R and D Centers (Chase, 1964; Clark and Hopkins, 1969; Gideonse, 1970).

Appropriately, since the LRDC had developed Individually Prescribed Instruction (IPI) and the Primary Education Project (PEP), both structured curricula, the design model selected for the training program was based on the structured or adaptive curriculum model. Lindvall and Cox (1969) have identified the components of this model as:

1. Sequences of instructional objectives to define the curriculum
2. Instructional materials to teach each objective
3. An evaluation procedure for placing each pupil at the appropriate point in the curriculum
4. A plan for developing individualized programs of study
5. A procedure for evaluating and monitoring individual progress.

Procedures developed for application of the structured curriculum model to social studies (Gow, 1972) were selected for the design of the curriculum training materials, with a self-instructional format

(Gow, 1972/73) which would allow students to assess their own needs and develop their own programs of study.

When the University of Pittsburgh inaugurated a pilot external studies project, a major part of these self-instructional materials became a post baccalaureate course in the design and development of curricular materials and the model for individualization of other University courses for extra mural, self-instructional studies. The PIC Model's content and component analysis procedures based on structure of the disciplines seemed to be uniquely suited to the complex subject matter of higher education, and the format was especially appropriate to meet the problems of extra mural education.

THE MODEL

The model, which evolved out of the efforts described here, is termed a Process Model for Individualization of Curricula to distinguish it from other structured curriculum models. While it is comprised of the usual structured-curriculum components and procedures (Gagne, 1965; Mager, 1962; Nitko, 1972; Bloom, 1956; Resnick and Wang, 1969) there are fundamental differences in the techniques for establishing instructional sequences and structuring hierarchies. In addition, there is a systematic attempt to apply the information we now have from the expanding field of instructional psychology to the design of curricula. The model itself is adaptive and provides a vehicle for the incorporation of new knowledge about the learning process as it is acquired.

The persuasive case for the teaching of the fundamental concepts and inquiry, to promote transfer and acquisition of intellectual skills, was made as far back as 1929 by Whitehead (p. 21) and 1938 by Dewey (p. 30), but it was Bruner's The Process of Education (1960) which had a major impact on the curricula created during the Reform Movement of the Sixties. In Bruner's words:

> "To understand something as a specific instance of a more general case ... is to have learned not only a specific thing, but also a model for understanding other things like it that one may encounter."
> (Bruner, 1960, p.25)

To know method, another element of structure, is to know how to find out more about a subject. The processes the student uses are the intellectual skills he needs if he is to acquire, organize and use the information fundamental to the discipline.

In addition, development of the concepts, which are elements of a discipline, is a process itself. Concept accommodation takes place as concepts become integrated into the student's frame of reference. Concepts grow and change instead of remaining static over time. Also, concepts are idiosyncratic because each individual's experience is unique. Individualized instruction based on concepts is therefore intrinsically individualized as well as adaptive to each student's needs.

Many quality curricula have been built on structure of disciplines in the past decade. (AAAS Science; BSCS Biology; SMSG Math; Taba Social Studies; Senesch Economics). Although Bruner seems to have become somewhat disenchanted (1971) with the ideas espoused by The Process of

Education, at least for the elementary and secondary years, his attitude apparently reflects a new concern for the importance of initiative and motivation to learn.

At the University level, however, discipline structure remains an essential consideration in curriculum design. Structured university education should focus on the processes which provide the student with the ability to learn independently. The PIC Model uses the fundamental concepts, principles, generalizations and methods of the discipline as the foundation for curriculum design and the basis for development of objective hierarchies and sequencing of instruction.

The Taxonomies of Bloom (1956) and Krathwohl (1964) are also used in the development of hierarchies. When curricula are analyzed, it is found that they seldom teach and test beyond the third level of Bloom's Taxonomy (Cox and Wildemann, 1970, pp. 24,26,38,42). Yet, we know that higher level skills transfer or facilitate learning (Gagne, 1971, p. 116; Bloom, et al., 1971, p. 122). The PIC Model, therefore, uses the Taxonomies as tools in the design process.

A further essential procedure to maximize the effectiveness of a structured-curriculum is the systematic application of research-based instructional strategies appropriate for the student, the subject matter and the objectives. The model borrows, pragmatically, from developmental, behaviorist or cognitive theory for selection of these strategies.

The Process Model prescribes structured curriculum components and describes procedures for building each component. The curriculum designer is encouraged to establish his own procedural sequence, rather than follow a linear systems approach, because on-the-job experience has revealed that curriculum design is a highly complex and personal process. It involves backward steps to revise a previously written portion in the light of each forward step.

DESIGN PROCEDURES

It is in identifying the first component of the structured curriculum, sequences of instructional objectives to define the curriculum, that the PIC Model differs appreciably from most design procedures.

The PIC Model uses the usual content and component analysis procedures (Gagne, 1968) but adds to them: (a) concept analysis and (b) systematic sampling of skills.

Content is defined for this model as the people, information, events and data at the knowledge level (1.32 and below) of the cognitive *Taxonomy*. Content is selected because it represents the positive or negative instances of the basic concepts which are most appropriate for the student population and for the level of the instructional sequence based on our present knowledge of concept learning. A variety of concept instances may be identified making it possible for the specific content he will study to be chosen according to the individual student's interest. Instead of concepts being developed as a by-product of the study of content, the facts, events and data of content are used to encourage conceptualization. The focal point is the concept.

For an already existing course which is being individualized, the course outline provides the content scope and sequence. For a new course, it is necessary to do a content analysis, ordering the subject matter chronologically, by topic or by whatever logical organization the curriculum designer has selected.

The fundamental concepts of the discipline which the course teaches are identified. This process may be called a concept analysis since it identifies the concept hierarchy or inter-relationships of the conceptual structure. A concept analysis produces a hierarchy of subconcepts, concepts, principles and generalizations for each unit of instruction.

To perform a concept analysis, the curriculum designer begins with a generalization and works backward asking what principles the students must know and be able to apply in order to understand this generalization. Then he asks what concepts he must know, and be able to identify examples of, in order to understand this principle. In this fashion, he works back to subconcepts that the student may be expected to know and be able to use. Often, specification of these elements of the discipline structure leads to addition of concept exemplars or reordering of content.

The PIC Model requires explicit identification of skills and methodology of the discipline and the use of Bloom's Taxonomy to select intellectual processes to incorporate into the course. The Taxonomy is used, in other words, to generate objectives. The process of expressing the objectives of the course behaviorally involves expressly sampling higher taxonomic level skills.

The curriculum designer combines the products of the content and concept analyses, merging them with the selected skills and expressing the behavior in objectives which state what the student does , under what conditions and how well he does it (Mager, 1962). In constructing the instructional hierarchy, all of the following are considered: logical order of content and concepts, sequence of elements of discipline structure, and taxonomy levels of skills. To teach students the processes of learning, the intellectual skills and methods of the discipline are practiced on content and concepts.

In his early writings, Gagne used the terms "concepts" and "principles" in his hierarchies. Later, he changed concepts and principles to concept learning or classifying and applying rules or principles. The original use of these terms and the subsequent change reflect the problem which the PIC Model attempts to solve.

Concepts may be both knowledge and process. Therefore, they are inherently different from both content,as facts, events, people and data, and skills . When content includes concepts this dual function of concepts causes great difficulty in structuring hierarchies, especially when dealing with complex subject matter. By separating content analysis from concept analysis and component analysis this problem is eliminated.

The second component of a structured-curriculum, instructional materials to teach each objective, requires the curriculum designer to use his teaching skills to move the student from his entering behavior to mastery of the terminal objectives of each lesson. It is in the degree of specificity of design strategies and the technique of recording the rationale for them,that the process model differs from most structured curriculum models.

The PIC Model requires that definition of each pedagogical decision of lesson writer be explicit. A planning form calls for listing of the objectives' prerequisite behaviors and the activities the student will participate in or tasks the student will perform. Most importantly, the lesson rationale defines and explains the method, mode, setting and instructional strategies used in the lesson. This requires a systematic examination of each element which must be matched to achieve maximally effective instruction.

The careful specification of strategies, and the systematic attempt to relate the lesson design to the requirements of the student and the subject matter and to justify that match by means of a lesson rationale eases formative evaluation procedures. It becomes possible to locate and change instructional strategies found to be ineffective, without altering other elements of the curriculum. The lesson rationale technique can facilitate evaluation of different strategies and development of more effective instructional materials.

The PIC Model does not differ appreciably from other such models in its procedures for development of the final three components of the structured curriculum: An evaluation procedure for placing each pupil at the appropriate point in the curriculum; a plan for developing individualized programs of study and a procedure for evaluating and monitoring individual progress. It employs the usual criterion-referenced tests: diagnostic, placement, curriculum embedded or unit sub-tests and post-tests.

The model does, however, include a procedure for selecting testing points to make testing more efficient. By charting each unit objective hierarchy (Nitko, Swanson, 1968), it is possible to select the optimal testing points which can reduce the number of necessary tests. (See Appendix III). Since it can be assumed that mastery of earlier sequential objectives has preceded mastery of later ones, branch terminus objectives may, in many cases, be optimal testing points.

Sometimes there are two terminal objectives; one a cumulative or culminating objective and the other a synthesis objective. A cumulative objective is essentially the sum of all the other objectives. A synthesis objective goes beyond this to incorporate the student's own perspective, solution or organization of the knowledge and skills of the hierarchy. The decision on whether to test one or both or whether to demand mastery of both, depends on diagnosis of the student's present requirements. For example: Suppose a student were studying social studies and there were two sequential objectives at the top of a charted unit hierarchy. He mastered the first which was cumulative, but could not master the final objective which required him to formulate a generalization. More examples of the concept in additional optional materials might lead him to the generalization, or it might be deferred until his next encounter with the concept. (See Appendix IV)

Finally, the PIC model, because it is a process model, can be used to produce structured curricula written in advance of the instructional event and still feature open-ended individual inquiry as a possible design option. Since the focus is on processes, and instruction is carefully sequenced and written to teach process, criteria can be established for unique responses resulting from independent research or creative production. The product can be evaluated in terms of the evidence it provides of the processes used to produce it. Self-evaluation can be accomplished by use of criteria and process check-lists.

THE FORMAT OF THE CURRICULUM COURSE

Each unit of the curriculum course based on the PIC model includes objectives, a charted objective hierarchy, study guides, answer keys, an overview, pertinent reprints of journal articles, a bibliography and a post-test. Although the format is particularly suited to mature students capable of self-direction, it can be used for instruction at any grade level, including computer assisted or teacher or aide monitored instruction, since all components of the instructional package are cross-coded. Curriculum-embedded test items, study guide tasks and sources for these tasks are coded to the objectives.

Students are guided in their choice of objectives by the pretest and their own aims. Individual differences among extra mural students may be expected to be greater than among university undergraduates or graduate students. Therefore, the pretest directs students to remedial units and permits them to "test out" of units they do not need. Additional sources, listed in the bibliography, can be used to remedy deficiencies in comprehension or skill revealed by failure to master test items or study guide tasks.

This format makes it possible for the student to determine his own placement in the program, plan his own program of study and monitor his own progress.

INDIVIDUALIZED APPLICATION OF THE MODEL

The curriculum course which teaches the design model described in this paper also teaches the instructional theory on which the PIC model is based. The procedures for designing curriculum components range from simple procedures to convert a traditional course to an individualized one to highly complicated procedures for creating an adaptive instructional environment. Knowledge of the theoretical basis for the design of instruction makes it possible for the student curriculum designer to make an informed judgment about the degree of structure he needs and wants to incorporate in his course and to selectively study as much as he needs to know to accomplish those ends.

For example, the instructional designer who will be employed at an R and D Center would need to learn some of the highly sophisticated techniques for validating instructional hierarchies, while this might not be necessary or feasible for university professors who cannot devote considerable time to individualization of their courses. Imposing these techniques on teachers and curriculum specialists in schools might discourage further efforts towards structuring effective individualized curricula. Rather, hierarchies can be considered tentative until empirically validated. An advantage to this latter stance is that it reinforces the attitude that curriculum development is a process and curricula are revisionary rather than static.

SUMMARY

The predictions and recommendations of the Carnegie Commission on Higher Education of the trend toward off-campus instruction of adults and the need for design of instructional units to meet the expected expansion suggest that a model is needed for the complex subject matter of the university. Such a model would contribute to the effectiveness and efficiency of higher education and particularly of extra mural adult education.

The Process Model for Individualizing Curricula (PIC) described in this paper, focuses on the structure of disciplines which make it appropriate for complex university-level content. Its trial run as a graduate course, developed by using the processes it teaches, has shown its effectiveness for teaching learning and instructional theory as well as applied curriculum design skills. This seems to support its usefulness for both theoretical and applied courses.

The highly structured unit design and self-instructional format recommend the total design package for use in in-service teacher training and for master's and doctoral programs as well as for teaching extra mural university curriculum design in any field.

APPENDIX I

PROJECT TO DESIGN NEW PATTERNS FOR TRAINING R&D PERSONNEL IN EDUCATION: CURRICULUM DESIGN AND DEVELOPMENT PROJECT

Course Outline: The Design of Individualized Instructional Curricula

Background to Instructional Design

I. Goals of Education

- A. Goal-setting
- B. The Reform Movement
- C. Individualization of Instruction

II. Psychological Bases of Instruction

- A. Learning Theories
- B. Instructional Theories
- C. Behavior Management

Theoretical Rationale for Instructional Design

III. The Subject Matter

- A. Structure of the Discipline
- B. Content Analysis

IV. The Skills

- A. Behavioral Objectives
- B. Taxonomies
- C. Component Analysis

V. The Instruction

- A. Instructional Methods and Strategies
- B. Media
- C. Classroom Environment

VI. Evaluation

- A. Formative
    - Feedback
    - Field Testing
    - Dissemination
- B. Summative

VII. School Organization

- A. Administrative Theory and Practice
- B. In-Service Teacher Training

Applied Instructional Design

VIII. The Design of Instruction

- A. Design Procedures
- B. Specification and Structuring of Objectives
- C. Criterion-Referenced Test Construction
- D. Selection of Instructional Methods, Media, Strategies and Setting
- E. Lesson Writing
- F. Management System Design

Curriculum Synthesis

IX. Instructional System Development Project

APPENDIX II

External Studies Course

Curriculum Design and Development --------- A Process Model for Individualization

Background to Instructional Design

I. Goals of Education

- Study Guide 1. Goal-Setting
- Study Guide 2. The Reform Movement
- Study Guide 3. Individualization of Instruction

II. Psychological Bases of Instruction

- Study Guide 1. Learning Theories
- Study Guide 2. Instructional Theories
- Study Guide 3. Behavior Management

Theoretical Rationale for Instructional Design

III. The Subject Matter

- Study Guide 1. Structure of the Discipline
- Study Guide 2. Content and Concept Analysis

IV. The Skills

- Study Guide 1. Behavioral Objectives
- Study Guide 2. Taxonomies
- Study Guide 3. Component Analysis

V. The Instruction

- Study Guide 1. Adapting Instruction to Learner Characteristics
- Study Guide 2. Instructional Methods, Media and Strategies
- Study Guide 3. Classroom Environment

VI. Evaluation

- Study Guide 1. Formative and Summative Evaluation in Curriculum Design

VII. School Administration and In-Service Training

Study Guide 1. Administration

Study Guide 2. In-Service Training

Applied Instructional Design

VIII. Design Procedures

Study Guide 1. Application of Instructional Theory to Instructional Design

Study Guide 2. A Process Model for Instructional Design

IX. Specification of Objectives and Structuring of Hierarchies

Study Guide 1. Identifying and Writing Objectives

Study Guide 2. Structuring and Charting Hierarchies

X. Criterion-Referenced Test Construction

Study Guide 1. Writing Test Items

Study Guide 2. Sampling Objective Domain and Assembling Tests

XI. Lesson Writing

Study Guide 1. Selection of Instructional Methods, Media, Strategies and Setting

Study Guide 2. Constructing a Lesson Rationale and Writing a Lesson

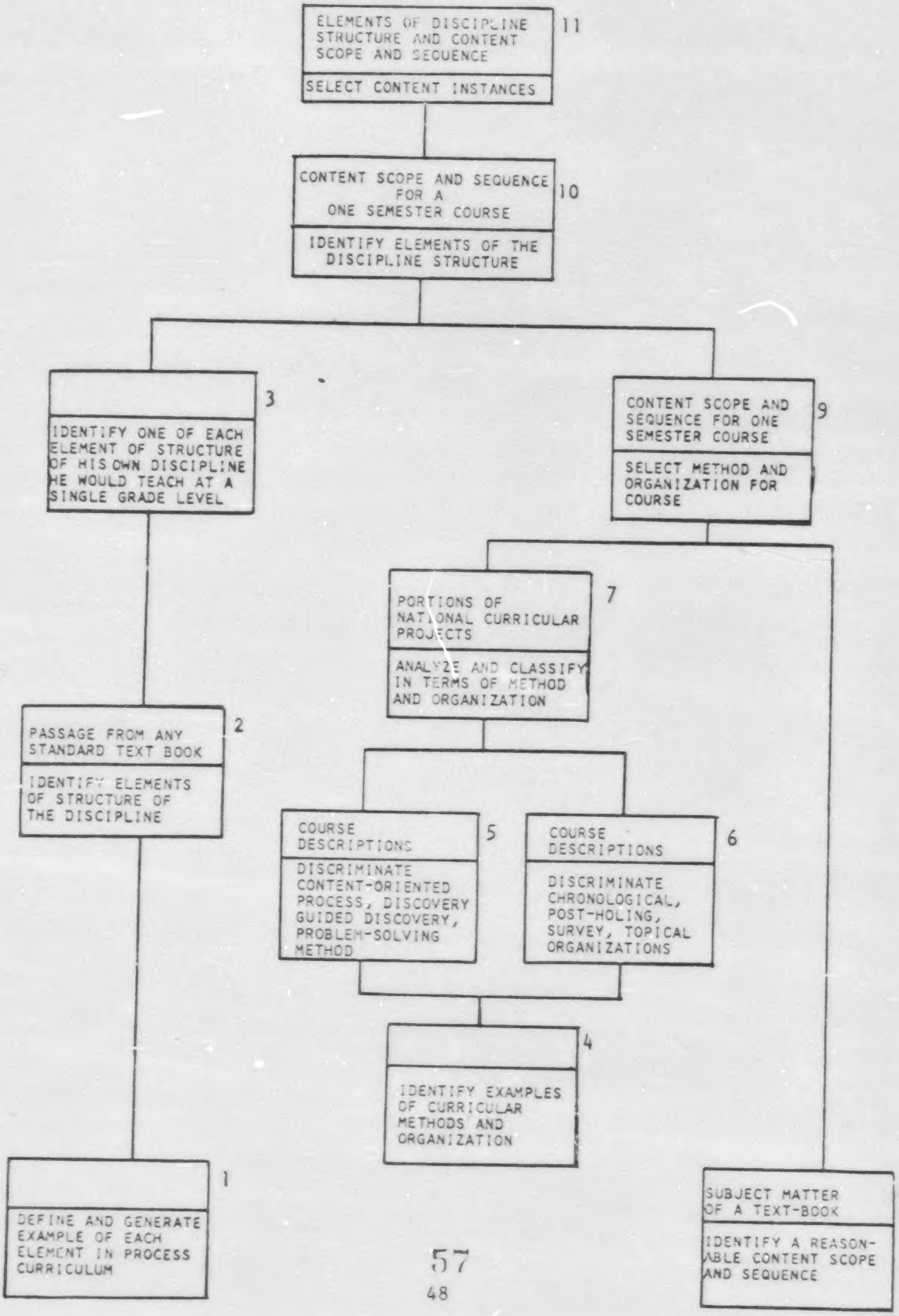
XII. Management System Design

Study Guide 1. Feedback System

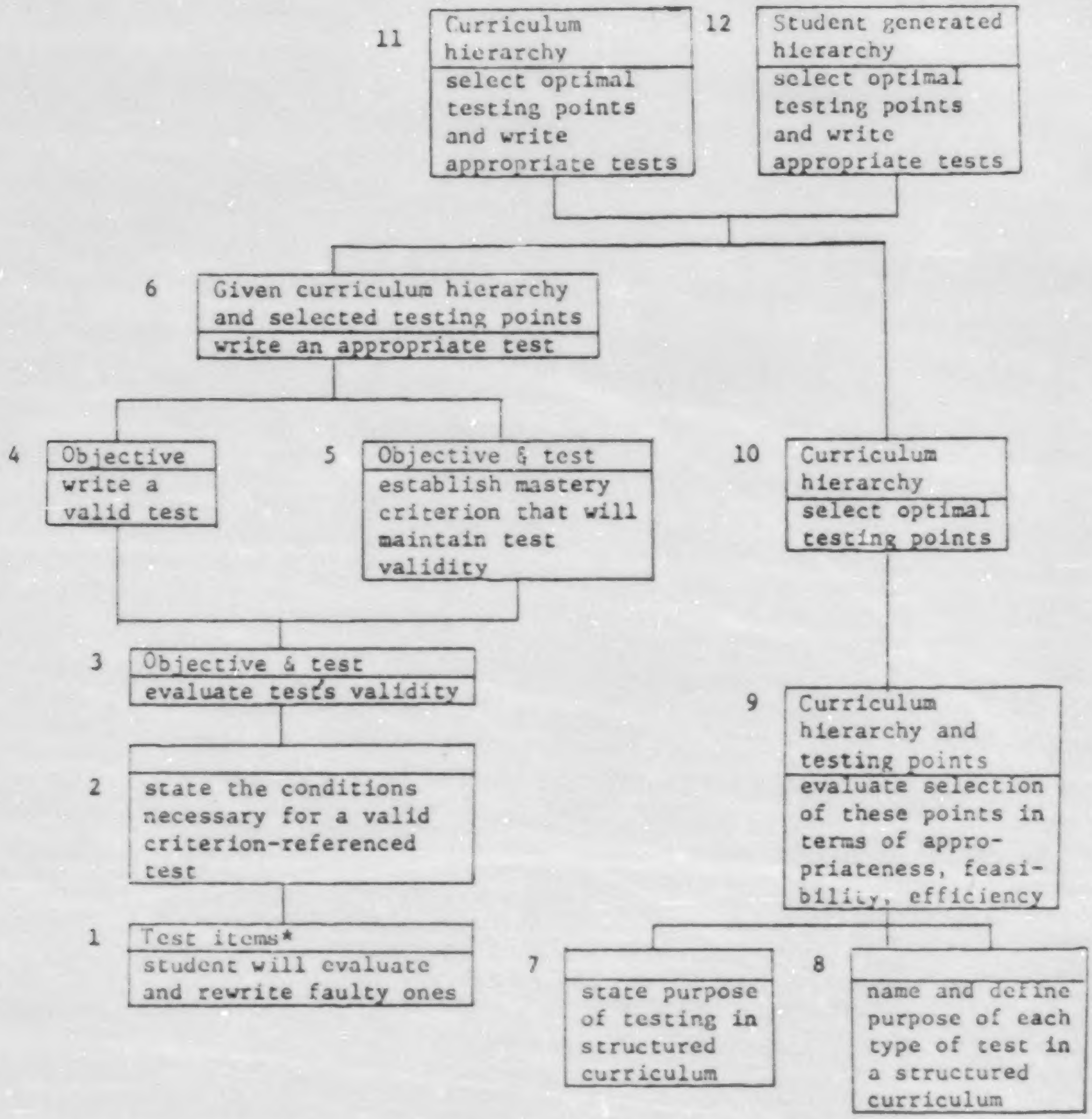
Study Guide 2. Staff Planning

APPENDIX III
Examples of Charted Hierarchies

D. HIERARCHY


ELEMENTS OF DISCIPLINE STRUCTURE AND CONTENT SCOPE AND SEQUENCE
SELECT CONTENT INSTANCES
11
CONTENT SCOPE AND SEQUENCE FOR A ONE SEMESTER COURSE
IDENTIFY ELEMENTS OF THE DISCIPLINE STRUCTURE
10
3
IDENTIFY ONE OF EACH ELEMENT OF STRUCTURE OF HIS OWN DISCIPLINE HE WOULD TEACH AT A SINGLE GRADE LEVEL
CONTENT SCOPE AND SEQUENCE FOR ONE SEMESTER COURSE
SELECT METHOD AND ORGANIZATION FOR COURSE
9
PORTIONS OF NATIONAL CURRICULAR PROJECTS
ANALYZE AND CLASSIFY IN TERMS OF METHOD AND ORGANIZATION
7
PASSAGE FROM ANY STANDARD TEXT BOOK
IDENTIFY ELEMENTS OF STRUCTURE OF THE DISCIPLINE
2
COURSE DESCRIPTIONS
DISCRIMINATE CONTENT-ORIENTED PROCESS, DISCOVERY GUIDED DISCOVERY, PROBLEM-SOLVING METHOD
5
COURSE DESCRIPTIONS
DISCRIMINATE CHRONOLOGICAL, POST-HOLING, SURVEY, TOPICAL ORGANIZATIONS
6
IDENTIFY EXAMPLES OF CURRICULAR METHODS AND ORGANIZATION
4
DEFINE AND GENERATE EXAMPLE OF EACH ELEMENT IN PROCESS CURRICULUM
1
SUBJECT MATTER OF A TEXT-BOOK
IDENTIFY A REASONABLE CONTENT SCOPE AND SEQUENCE
8

D. Hierarchy


11 Curriculum hierarchy
select optimal testing points and write appropriate tests
12 Student generated hierarchy
select optimal testing points and write appropriate tests
6 Given curriculum hierarchy and selected testing points
write an appropriate test
4 Objective
write a valid test
5 Objective & test
establish mastery criterion that will maintain test validity
10 Curriculum hierarchy
select optimal testing points
3 Objective & test
evaluate tests validity
2 state the conditions necessary for a valid criterion-referenced test
1 Test items*
student will evaluate and rewrite faulty ones
9 Curriculum hierarchy and testing points
evaluate selection of these points in terms of appropriateness, feasibility, efficiency
7 state purpose of testing in structured curriculum
8 name and define purpose of each type of test in a structured curriculum

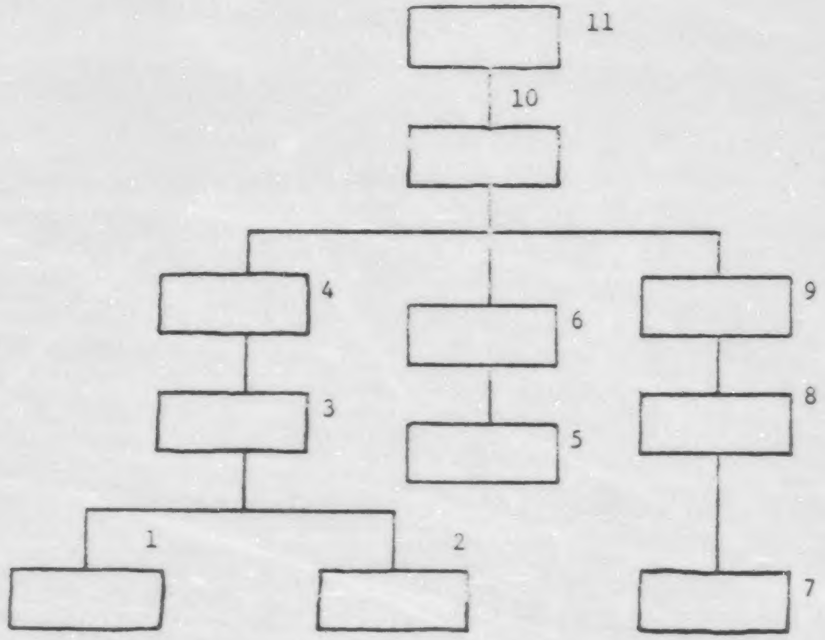
(Prerequisite, Unit II, Objectives)

*Multiple choice, true-false, short answer, matching, essay.

APPENDIX IV

NOTE: The following example of optimal testing points shows the structure only, not the specific objectives, in order to emphasize the general principle. This is done because, in specific instances, the testing points are a matter of judgment based on the objectives themselves. However, the optimal testing principle, used with discrimination, can increase testing efficiency.

Hierarchy and Testing Points



For pretest	4, 6, 9.
For CETs	4, 6, 9.
For post-tests	10, 11 or just 11.
For placement	1, 2, 4, 6, 7, 9.

Explanation

The testing of 4, 6 and 9 for the pretest would narrow the options sufficiently to be an economical procedure. If the student failed 4 he would start in 1. If he mastered 4 and 6, and failed 9 he would start in 7. If he mastered 4, 6 and 9, he would be given the post-test.

The CETs would be given for 4, 6 and 9 because they represent 3 different sub-hierarchies. Giving 10 would not indicate which of these 3 he had failed to master.

The post-test need only be on the final objective if it is a cumulative objective which demands behavior that is essentially the sum of all the other objectives. However if 10 were cumulative and 11 went beyond to synthesis, it might be wise to test both 10 and 11 to ascertain whether the student had mastered everything to and including 10. If he had, but failed 11, he would probably profit from more practice with different materials rather than repetition of the same lessons, or the final synthesis objective might be deferred.

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Appendix B

Unit Rating Sheets

1. Pilot test of materials
2. Field test of materials

UNIT CRITIQUE FORM
(Pilot Test of Materials)

Unit No. ________

Each of the following categories represents a particular aspect or section of the instructional unit. "Rationale," for example, refers to the rationale for the unit content presented at the beginning of each unit. Each category (section) of the unit should be evaluated on such bases as whether it was "clear," "concise," "effective in its goal," "weak," etc., i.e., on both positive and negative characteristics. Suggestions for revision should be included using specific examples. If any particular category is not relevant to the particular unit, omit comment. Be specific.

Rationale

Terminal objectives

Prerequisite objectives

Intermediate objectives

Evaluation Procedures

Pre-Post-Tests and CETS

Hierarchy

Activities

Speakers

Bibliography

Abstract/Exemplars

Worksheets/exercises

Supplementary materials

Class sessions

Tutorials/individual meetings

UNIT RATING SHEET: C & S 850
Design and Development of Curricular Materials (Field Test of Materials)

To assist us in improving this instructional unit for use by future students, please take a few minutes at the end of the unit to complete this record sheet, and return it in the enclosed envelope to the UESP office. The individual forms will not be seen by the instructor.

Name____________________

Date____________________

Unit____________________

Time Spent on Unit________________(in hrs.)

1. Please rate the following by circling the rating number that you feel best describes each item:

	Very High	High	Average	Low	Very Low
Subject matter relevancy to your own interests (professional or otherwise)	5	4	3	2	1
Clarity of the unit objectives	5	4	3	2	1
Degree to which the unit materials provided the information necessary to accomplish the unit objectives	5	4	3	2	1
Interest value of the unit materials	5	4	3	2	1
Difficulty level of the unit	5	4	3	2	1

2. Did you have problems with any of the unit objectives? Yes____ No____
If yes, list the objective numbers here.____________________

3. What did you like best about this unit?

4. What did you like least about this (including articles that were least productive)?

5. What specific changes would you recommend for improving the effectiveness of this instructional unit?

Summary Unit Rating Sheets

Unit I (now III)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	4	5	7		
2. The clarity of objectives	4	7	5		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	2	6	5	1	
4. The interest value of the readings	1	5	5	6	
5. The assistance of self-scored tests to self evaluation	5	7	5		
6. The instructional value of the exercises (if applicable to this unit	2	4	2	1	
7. The instructional value of the study guide(s)	4	10	3		

Summary Unit Rating Sheets

Unit II (now IV)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	5	5	3		
2. The clarity of objectives	8	4	2		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	5	6	3		
4. The interest value of the readings	2	9	2		
5. The assistance of self-scored tests to self evaluation	4	4	5		
6. The instructional value of the exercises (if applicable to this unit	3	7	2		
7. The instructional value of the study guide(s)	5	7	1		

Summary Unit Rating Sheets

Unit III (now V)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	7	6			
2. The clarity of objectives	5	7	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	4	6	2		
4. The interest value of the readings	1	2	2		
5. The assistance of self-scored tests to self evaluation	5	6	2		
6. The instructional value of the exercises (if applicable to this unit	4	7	2		
7. The instructional value of the study guide(s)	5	7	1		

Summary Unit Rating Sheets

Unit IV (now VI)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	7	3			
2. The clarity of objectives	6	4			
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	6	4	1		
4. The interest value of the readings	3	5	2		
5. The assistance of self-scored tests to self evaluation	4	4	1		
6. The instructional value of the exercises (if applicable to this unit	3	3			
7. The instructional value of the study guide(s)	5	5			

Summary Unit Rating Sheets

Unit V (now VII)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	7	1			
2. The clarity of objectives	8				
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	4	1	1	2	
4. The interest value of the readings	4	3	1		
5. The assistance of self-scored tests to self evaluation	3	5			
6. The instructional value of the exercises (if applicable to this unit	3	2			
7. The instructional value of the study guide(s)	4	2			

Summary Unit Rating Sheet

Unit VI (now VIII)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	1	3		1	
2. The clarity of objectives	3	1	1	1	
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	3			1	
4. The interest value of the readings	2	2		1	
5. The assistance of self-scored tests to self evaluation	3	1		1	
6. The instructional value of the exercises (if applicable to this unit	4	1	1		
7. The instructional value of the study guide(s)	3	2	1		

Summary Unit Rating Sheet

Unit VII (now IX)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	3	3	1		
2. The clarity of objectives	2	4	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		2	4		
4. The interest value of the readings	2	3	2		
5. The assistance of self-scored tests to self evaluation	5	1			
6. The instructional value of the exercises (if applicable to this unit	5	1	1		
7. The instructional value of the study guide(s)	3	3	1		

Summary Unit Rating Sheet

Unit VIII (now X)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	4	2	1		
2. The clarity of objectives	3	2	1	1	
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	2	1	2	1	
4. The interest value of the readings	4	2	1		
5. The assistance of self-scored tests to self evaluation	3		1		
6. The instructional value of the exercises (if applicable to this unit	2	3			
7. The instructional value of the study guide(s)	1	2	1		

Summary Unit Rating Sheet

Unit IX (now XI)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	2	4			
2. The clarity of objectives	4	2			
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	2	2	2		
4. The interest value of the readings	1	2	3		
5. The assistance of self-scored tests to self evaluation	2	1			
6. The instructional value of the exercises (if applicable to this unit		1			
7. The instructional value of the study guide(s)	1	2			

Summary Unit Rating Sheet

Unit X (now XII)

(Instructor 1)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	1	2	1		
2. The clarity of objectives	1	2	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		4			
4. The interest value of the readings	1	3			
5. The assistance of self-scored tests to self evaluation	2				
6. The instructional value of the exercises (if applicable to this unit	1	1			
7. The instructional value of the study guide(s)	2				

Summary Unit Rating Sheets

Unit I (now III)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	3		2	1	
2. The clarity of objectives	1	2	3		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		2	1	2	1
4. The interest value of the readings		1	3	1	1
5. The assistance of self-scored tests to self evaluation	1	1	2	1	1
6. The instructional value of the exercises (if applicable to this unit		2	1	3	
7. The instructional value of the study guide(s)	2	1	2		1

Summary Unit Rating Sheets

Unit II (now IV)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	3	2	1		1
2. The clarity of objectives	3	2	2		1
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives	1	2	1	3	
4. The interest value of the readings	1	2	2	2	
5. The assistance of self-scored tests to self evaluation	1	2	1	1	1
6. The instructional value of the exercises (if applicable to this unit		5			1
7. The instructional value of the study guide(s)		5			2

Summary Unit Rating Sheets

Unit III (now V)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)		3	2	2	
2. The clarity of objectives		2	3	2	
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		2	1	3	1
4. The interest value of the readings		2	1	2	1
5. The assistance of self-scored tests to self evaluation		2	2	1	2
6. The instructional value of the exercises (if applicable to this unit		2	2	2	1
7. The instructional value of the study guide(s)		5			

Summary Unit Rating Sheets

Unit IV (now VI)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	2			1	
2. The clarity of objectives	1	1	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		1	1	1	
4. The interest value of the readings			2	1	1
5. The assistance of self-scored tests to self evaluation		1	1	1	
6. The instructional value of the exercises (if applicable to this unit				1	
7. The instructional value of the study guide(s)		1	1		

Summary Unit Rating Sheets

Unit IV (now VI)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	2			1	
2. The clarity of objectives	1	1	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		1	1	1	
4. The interest value of the readings			2	1	1
5. The assistance of self-scored tests to self evaluation		1	1	1	
6. The instructional value of the exercises (if applicable to this unit				1	
7. The instructional value of the study guide(s)	2				

Summary Unit Rating Sheets

Unit V (now VII)

(Instructor 2)

	Very Good	Good	Average	Poor	Very Poor
1. The subject matter relevancy to your own interests (professional or otherwise)	2		2		
2. The clarity of objectives	2	1	1		
3. The degree to which the objectives and materials provide the information necessary to accomplish the unit objectives		1	2	1	
4. The interest value of the readings		1	2	1	
5. The assistance of self-scored tests to self evaluation	1	1		2	
6. The instructional value of the exercises (if applicable to this unit		1	1	1	
7. The instructional value of the study guide(s)	1	1	1	1	

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CURRICULUM DESIGN AND DEVELOPMENT PROJECT

Final Report - Volume 2

APPENDICES C - F

Learning Research and Development Center
University of Pittsburgh
December, 1973

EA 007 792

CURRICULUM DESIGN AND DEVELOPMENT PROJECT

Volume 2

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Appendix C

The Students

1. Evaluation of their training by the R & D students.

2. Reports on R & D students by their Supervisors and Colleagues.

MEMO TO: Doris T. Gow

FROM: Diane J. Davis

DATE: December 6, 1973

SUBJECT: PIC Training Materials

As a student who has completed training in the design and development of curriculum through the use of your materials, I would like to share with you some of my impressions concerning those materials.

I feel that one of the most important characteristics of the curriculum is the way in which it is organized. The individual curriculum units have enabled me to use these materials extensively as a resource in my continuing work as a curriculum specialist. I am currently employed in this capacity at the University External Studies Program and my work there involves assisting faculty members in preparing individualized structured materials for use by adults studying independently at home. It has been extremely helpful to me to be able to refer to these materials whenever we are faced with a particular developmental problem.

Another aspect of the materials which has been extremely helpful in this sense is the use of primary sources in the reading material, It is helpful, when preparing any curriculum rationale, to be able to refer to these sources in identifying or defending a particular appropriate strategy or procedure, for example.

My own training, through the use of these materials, has proven most effective for my current responsibilities as a curriculum specialist here at the External Studies Program. I have been able to use my skills in curriculum development to assist our faculty in designing courses that have lead to student success in this Program. The use of these materials for graduate students in this Program illustrates the wide variety of both student interests and student characteristics for which the materials are applicable. Although my own background was not specifically in the field of education, I was able to use these training materials successfully to achieve skills in designing and developing curricular materials.

The effectiveness of the R & D Training Program can best be evaluated through an analysis of its constituent parts and their interactions with one another. For purposes of simplicity, let us view the program as the sum of three components: 1) The materials, including the unit materials and readings; 2) The interaction sessions including those between the students and staff (classroom meetings) and those among students only (group activities); and, 3) The practicum and internship experiences. Each of these contributed in unique ways to the program as a whole. The last two components, for example, will invariably differ markedly in their contributions and value for every group of staff and students and for every individual. Conversely, the materials should be transferable to other situations with little difficulty. Each component shall thus be examined individually.

The materials were to a large extent individualized. In this form, they provided an excellent framework from which to pursue the study of both the basic principles of sound curriculum development and also of specialized fields of individual interests. Perhaps the most valuable aspect of the materials, however, was the manner in which they were organized and in which the content was sequenced. The process of transition from one state of knowledge to the next, more sophisticated state was orderly and relatively smooth. There were, of course, at first many frustrating moments as enthusiastic students desired to quickly comprehend the intricacies of what was only meant to be an overview of things to come. After attaining a more global picture, beginning again in detail was most instructive. In retrospect, the manner in which knowledge and skills were slowly built upon one another was remarkably efficient. Finally, a great deal was learned from observing the manner in which the materials themselves were developed by the staff and from participating in minor ways as a group in an attempt to play a more active role in our own education.

A reciprocal relationship seemed to exist between the materials and the interaction sessions. For one, the classroom and group meetings certainly enriched the materials greatly. It seems, however, that the quality of the materials and their organization enabled the meetings to be as effective as they were by providing a solid, informative basis for discussion and debate. Basically, the interaction sessions provided a format in which the validity of newly acquired ideas and concepts could be tested and organized into cohesive statements of educational philosophy and method. The interaction session, along with the internship experience, also allowed for previously acquired knowledge to be placed in a more realistic context.

The internship experience was something of a crowning touch. It was the only logical culmination to months of preparation: The chance to test our abilities "on-line." It provided the essential opportunity to synthesize previously learned knowledge, concepts and skills along with those necessarily acquired in the particular, specialized internship. The internship also provided possibly the best test of the materials. In this respect, I believe the materials were successful.

In conclusion, I consider the most interesting and rewarding components to be the interaction sessions (especially group) and the internship, but the most essential to be the materials themselves. All three components were indispensible in making the program a most successful enterprise.

MEMO TO: Dr. Doris Gow

FROM: S. Claire McCormick

DATE: December 10, 1973

SUBJECT: Report on Experiences in Program 2: Curriculum Development

Program 2 (The Curriculum Design Course) answered a need which I had felt in trying to initiate change toward a more individualized learning environment in two different small high schools. Implementing new forms of scheduling was comparatively easy to manage, but assisting teachers in planning really individualized instructional sequences was a challenge I felt I was not quite meeting. It was gratifying to me to find a program which met this need, and also took me beyond into the area of invention and design of new forms of curriculum.

There are three chief benefits which I gained from participating in the first year's training. First, the materials presented in the individual learning packages, taken as a whole, integrated new knowledge derived both from educational psychology and educational research as this knowledge applies to curriculum design and development. The systems model of curriculum design developed in this program is invaluable as a new way of looking at curriculum.

Second, the manner in which the units were constructed and the types of exercises included forced me into a more analytical way of thinking than I had been accustomed to use. This was good for me.

Third, the experience of doing individual projects and group projects was also good in that it encouraged independent exploration of a problem. I could not have produced my internship project without the prior training afforded by our program in curriculum development.

Finally, I believe that our instructors who designed this program are to be commended for pioneering in the development of learning packages on the graduate level. Also noteworthy is the fact that we as students were experiencing the kind of learning situation for which we were being trained to design and develop materials. This program has served to further define an area which is beginning to emerge as a discipline itself; namely, the technology of curriculum design.

T. Whiting

My R & D Training

Before coming to the University of Pittsburgh as a graduate student in the R & D Training Program, I had been working as an educational coordinator in a program where one of my major responsibilities was that of designing and implementing a curriculum for high school dropouts. I came to that job with only the experience of a secondary social studies teacher. I had had no training or experience in curriculum development. During that year, I examined many curricula designed for secondary students and based on the needs of the students in the program, I put together bits and pieces from these curricula and made a new one. To my amazement this "cut and paste" curriculum actually worked for those students. However, I was dissatisfied with this method of curriculum making and was really interested in learning how to design curricula. The R & D Training Program offered me the opportunity to acquire this skill.

A systems approach to curriculum development was offered to the students in the R & D Program. The significance of this approach was the idea that curricula should be designed and developed based on specific instructional objectives which, when met, can be objectively evaluated to measure their instructional effectiveness. Through pre-testing the student can enter the curriculum at his present level of competency, and, if the instructional methods are ineffective, feedback is provided into the system to help re-evaluate and correct the instructional process. This approach no longer places the responsibility for learning or "mislearning" on the student but places the responsibility on the instructional material(s) designed to translate the objectives to the student.

Over the past 2 1/2 years, the R & D Training Program has provided me with many valuable educational experiences. The most valuable experience was that of working as an intern with Dr. D. Gow on an experimental social studies curriculum for third graders in Frick School. Frick is an inner-city elementary school and my interest was focused on curriculum development in the affective domain for the urban elementary school child. Dr. Gow's social studies curriculum encompassed both the cognitive and the affective domain, utilizing social science concepts and methodology to approach the affective area of learning. The internship provided me with the opportunity to apply many of the theories and skills taught in the first year of the program, and to observe first hand the results of their use. Working on the social studies curriculum also allowed me to practice my belief that curricula should not be developed in a vacuum, but with the designer in close contact with the faculty and students for whom the curriculum is being designed. The design and development of a curriculum is at times a slow process which requires patience and I learned to be more patient and not to expect everything to fall into place at once. Since I was working in an urban elementary school, I also had to learn how to cope with many of the problems which arise in such a system. But, the greatest reward came when observing how well something worked when it was used to teach a concept to a small child, something that you had helped to create. Curriculum development is at best a skill which requires time, practice, patience and ingenuity to acquire. The R & D Training Program provided me with the opportunity to begin to acquire and practice this skill and it also gave me the incentive to develop more ideas for futher research into the area of curriculum development in the affective domain.

UNIVERSITY OF PITTSBURGH

TO: Doris T. Gow

FROM: Samuel Deep, Director, University External Studies Program Sam Deep

DATE: December 5, 1973

SUBJECT:

Diane Davis, a student from the L.R.D.C. Training Program in Curriculum Development, has worked as a curriculum and instructional specialist with this Program since its initiation in the Fall of 1972. As Director of the Program since February of this year, I have been able to observe and evaluate her work here in terms of the effectiveness of her training for the type of curriculum development required by this Program.

The University External Studies Program provides college level courses based on individualized structured materials, for independent study by adult students who are unable to attend regularly scheduled University classes due to such things as geographical location, or job and family responsibilities. The curriculum and instructional specialists in this Program are required to work with faculty members to assist them in designing instructional materials which are appropriate and effective for the students we serve. This work requires such skills as:

Analysis of Course Material in three areas:

- Component Analysis
- Content Analysis
- Concept Analysis

Evaluation of appropriate instructional strategies

Coordination of Development of Goals, Objectives, Text, and Testing Materials (both diagnostic and evaluative)

Preparation of Instructional Strategies for On-Campus Work-Shops

Analyze course evaluation and develop strategies for change when considering revision

Analyze changing student needs as they apply to course development.

Analyze professional skills using feedback from:

- faculty
- staff colleagues
- student evaluation of courses

Continuing exploration of new instructional strategies as they apply to curriculum development.

Assist students who have problems with instructional materials.

Diane's formal training in curriculum has come solely through the L.R.D.C. training Program and the PIC model. This training has proven extremely effective for meeting the instructional goals of this Program.

SDD/pk

Copy for Diane

FACULTY OF ARTS AND SCIENCES
UNIVERSITY OF PITTSBURGH
PITTSBURGH, PENNSYLVANIA 15213

OFFICE OF THE DEAN

25 May 1973

Dr. John L. Morgan
LRDC
8th floor, LIS Building

Dear Dr. Morgan:

I am pleased to write to you about Diane Davis.

Ms. Davis has helped me in many ways in the several External Studies courses that I have taught. Her ideas about curriculum, study guides, and arrangement of materials have enriched my courses much. She has been most cooperative in doing a wide range of assignments in sustaining a meaningful relationship with the students. Without her help, the burden of handling these courses, as well as their effectiveness, would have been lessened materially.

Sincerely,

Reuben E. Slesinger
Associate Dean and
Professor of Economics

RES:mo

LEARNING RESEARCH AND DEVELOPMENT CENTER
UNIVERSITY OF PITTSBURGH • PITTSBURGH • PENNSYLVANIA ~~15213~~ 15260

UNIVERSITY DRIVE
412–621-3500

M E M O R A N D U M

TO: John Morgan

FROM: James Holland

DATE: 8 June 1973

SUBJECT: Recommendation for Diane Davis

Last year Diane carried out an independent research project with me. The project required the implementation of our pre-school skills work in Frick School. This gave me an opportunity to observe Diane's skill in an unusually wide range of attibutes. She had to provide liaison between the lab and teachers in the school, had contact with the students, had to systematically collect data, take part in conferences with the school administration, LRDC faculty, write up a careful evaluation of all problems found in implementing the program. Diane proved to be a thoroughly capable professional in all aspects of her work. She showed great responsibility and initiative in handling this project. She proved to be a sensitive, critical observer and kept thorough protocols; she was able to handle the rather difficult problem of working with so many different people having so many different objectives. All in all, I am thoroughly confident in Daine's ability to make important contributions to educational development. She is also a pleasure to be around and the kind of person I would welcome as a colleague.

JGH:rh

LEARNING RESEARCH AND DEVELOPMENT CENTER
UNIVERSITY OF PITTSBURGH • PITTSBURGH • PENNSYLVANIA 15213
DIRECTOR: 208 M. I. BUILDING
LABORATORIES: M. I. BUILDING
ADMINISTRATION: 160 NORTH CRAIG STREET
PHONE XXXXX
624-4884

M E M O

TO: Doris Gow

FROM: Dick Roman

DATE: December 3, 1973

RE: Nicholas Laudato's Training

Nicholas Charles Laudato interned with the Computer Assisted Instruction in Problem Solving Project after he was trained. At the time he joined us he had no previous computer experience and no direct instructional experience except what he had learned in the R & D program. The specific skill required to write and evaluate computerized instruction differ in many particulars from those used in more traditional curriculum, and someone trained specifically for other media often can not make the transition easily. Nick's training however was immediately transferred to the new situation; I believe that speaks highly for the R & D program as well as for Nick himself.

The specific skills Nick brought with him include:

the ability to observe and describe the actions students took on a computer program. He was able to separate what he saw from what he inferred.

the ability to diagnose difficulties in lessons accurately and make moderate interventions with the students to correct the difficulty.

the ability to do task analysis on specific objectives and design curriculum that fit the constraints of the available instructional paradigms.

the ability to generate several alternative solutions to an instructional problem and to choose the best alternative to achieve his goals.

I believe that the year of training Nick received provided him with extremely useful skills and concepts for work in the area of curriculum development.

RAR/met
attachment

LEARNING RESEARCH AND DEVELOPMENT CENTER
UNIVERSITY OF PITTSBURGH·PITTSBURGH·PENNSYLVANIA 15260

TO: Doris Gow

FROM: Isabel Beck Isabel Beck

DATE: December 4, 1973

RE: Sister Claire McCormick's Internship with the Reading Project

Sister Claire McCormick was an intern with the reading Project of LRDC during the fall and winter terms 1972-73. The LRDC Reading Project is currently involved in the development of an individualized-adaptive reading system for the primary grades, known as the New Primary Grades Reading System (NRS). Sister McCormick became associated with the Reading Project when approximately one-third of the new reading system had been developed. She quickly demonstrated that she was extremely well-versed in many aspects of instructional design.

As a summer project prior to becoming an intern, Sister McCormick prepared an indepth analysis of some of the instructional materials contained within certain levels of NRS. She analyzed the NRS materials for strategies of instruction based in research. In order to carry out the analysis, Sister McCormick developed a model for evaluating the audio lessons which included: 1) inducing the behavioral objectives from the instructional materials, 2) inducing the cognitive skills required to respond to the materials, and 3) analyzing the individual frames or groups of frames for stimulus, prompts, response, and management elements. The purpose of the analysis was to provide the evaluator of curriculum materials with enough information to determine the quality and intensity of learner interaction required by the materials.

As an intern, Sister McCormick became involved at various times with almost all the aspects of the continuing development of NRS. She designed cassette response pages and wrote the accompanying audio scripts; she wrote independent seatwork which follows the cassette lessons; she wrote read-alone stories and designed games, the content of which corresponds to specific instructional levels of NRS; she observed NRS being used in developmental classrooms and taught certain lessons to the children in these classrooms. And, like all Reading Department staff members, she assisted with anything that needed to be done to facilitate the development of the program, such as proofreading copy of the children's workbook pages and checking audio cassettes. Sister McCormick was able to fit her individual assignments into the perspective of the development of the total reading system.

It was clear from the results demonstrated while she was an intern that Sister McCormick had received excellent training in curriculum design and development, and that she was well-versed in the theories of instruction. Her work on the Reading Project showed that she could translate the theories she had learned into the development of an actual program.

Appendix D

Sample Student Work

A description of a portion of Diane Davis' work as an intern at the University External Studies Program. This was presented by Diane at the AERA Meeting in New Orleans, Feb., 1973.

THE DEVELOPMENT OF AN INSTRUCTIONAL DELIVERY SYSTEM FOR EXTERNAL STUDIES IN HIGHER EDUCATION

John L. Yeager & Diane J. Davis

University External Studies Program
School of General Studies
University of Pittsburgh

Presented at AERA Annual Meeting
February, 1973 - New Orleans

THE DEVELOPMENT OF AN INSTRUCTIONAL DELIVERY SYSTEM FOR EXTERNAL STUDIES IN HIGHER EDUCATION

John L. Yeager & Diane J. Davis

Background

The establishment of non-resident educational programs in higher education has been receiving an increasing amount of attention in an effort to meet the diverse educational needs of the American public. Although a number of prototype systems exist that provide such instruction, there have been few attempts in this country to develop non-resident educational systems that include both a flexible delivery mode and quality instruction. The primary requisites in the development of a non-resident educational program are: (1) that a delivery system be developed that has the characteristics of low cost, wide-area distribution and be available to the student on demand, (2) that the program insures that the content being transmitted is of high academic quality, (3) that the program provides for student motivation, and (4) that alternative learning modes be made available to accommodate individual student learning preferences.

The University External Studies Program (UESP) at the University of Pittsburgh began with the assumption that there existed, in Western Pennsylvania, certain individuals who had not been afforded access to higher educational opportunities. The purpose of the External Studies Program is to provide extended educational opportunities to those segments of the population that are currently denied access to undergraduate and graduate instruction because of geographical and situational factors. That is, there are at present a number of individuals who cannot avail themselves of the opportunity to pursue higher education because of such factors as commuting distance to and from an institution, family responsibilities, physical handicaps, and work situations such as those entailing irregular schedules. In addition, there are individuals who wish to change positions or careers and desire to obtain new credentials or to further their education and yet must simultaneously maintain and support themselves or other individuals.

Central to the development of a program designed to meet these individual educational needs, is the specification of a delivery system for the dissemination of instruction. This delivery "system" consists of the instructional delivery model and the instructional support systems. The "instructional delivery model," then, refers to the curricular methods, mode, and media chosen for transmitting the course content. There is an interacting relationship between the characteristics of the instructional delivery system and the goals of the external program itself. That is, a number of specific assumptions are derived from the philosophy and goals of an external study program that act to limit and define the parameters of the delivery system itself.

1. The system must be flexible in terms of its accessibility and state of "readiness" or availability to the learner at any given point in time.

2. The system must permit the student to assume a great deal of independence and responsibility for pursuing specific learning goals.

3. The system must provide instruction that is adaptive to the individual needs of the learner.

Each of the delivery modes described below, combined with the support systems discussed later, constitute a separate type of delivery system that the UESP Program attempted to implement and examine.

It is within this context that the University External Studies Program recruited faculty members who, together with the Program staff, developed and offered five external studies courses which were the equivalent of on-campus courses and which represented four alternative instructional delivery modes. Each system served as one means for attempting to meet the diverse instructional needs of the UESP students. The Program was able to obtain background data for 121 of the 153 who enrolled in UESP courses during the initial offering. An analysis of this background information shows that these students ranged in age from 19 to 55 and the majority did have employment or family responsibilities which prevented them from attending regularly scheduled on-campus classes. The reasons, as the students listed them, for preferring this type of study to traditional classes included the following: family responsibilities, work schedules, time conflicts with regular classes, and travel inconvenience. Less frequently mentioned were health and parking.

THE DELIVERY SYSTEMS

General Characteristics

One of the primary goals of this External Studies Program was to develop a system which was easily accessible to the student at any point in time. It was for this reason that written, self-instructional materials were chosen as the primary medium for the delivery of external studies courses to these students. Written materials have the advantages of being readily accessible to the student at any time and of being adaptable to the individual needs of the learner as well as to a wide variety of content. In addition, they are relatively inexpensive when compared to the other media and can be used independently from any other media.

For this Program, the individual faculty members were requested to develop self-instructional materials or to select from written materials already available in their field. They were assisted by curriculum specialists from the UESP staff and all materials were extensively reviewed before being distributed to the external studies students participating in the Program. The four types of delivery models developed are as follows:

1. Television with Supplementary Materials
2. Programmed Instruction with Supplementary Materials and Readings
3. Reading Lists with Summaries and Supplementary Materials
4. Structured Curriculum based upon a Process Model for the Individualization of Curricula

In addition to the curricular packages, based on each of the four delivery models, each system included the following supplemental support systems:

An Advisement-Counseling System. The function of this system was to provide the student with advisement and counseling personnel who could assist them with personal or professional counseling needs. The main portion of this service was provided through the staff of the School of General Studies which included personnel specifically trained for these purposes. In addition, the UESP system operated primarily in providing the following kinds of supportive assistance:

a. Information concerning UESP courses and the award of formal college credit.

b. Procedures for registration for UESP courses and assistance when special registration problems arose.

c. Assistance with difficulties in achieving course objectives and procedures for extending time limits to meet external pressures; encouragement when students encountered problems.

d. Providing a student manual containing information on how to study independently, as well as a map of the University indicating special resource areas and a list of courses to be offered the following term.

A Communications Support System. It was recognized by the UESP staff that since the student was primarily engaged in independent study, there was a pressing need to provide alternative ways by which the student would have access to the faculty and Program staff. The communications support system provided the student with the following means for communication:

a. Telephone communication - Students were given specific numbers to dial in order to reach the course instructors, the UESP staff, or specifically appointed teaching assistants who could assist them.

b. Student mailers - The students were provided with self-addressed forms which they could use for mailing in questions to the course instructor. There was space for the instructor response and students received an answer in as little time as possible.

c. Newsletter - Students received a newsletter four times during the term informing them of special dates and events which they should be aware of or which were relevant to their course interests.

d. Special memos - Special memos were prepared and mailed by the UESP staff when an instructor wished to make a special announcement to his students.

A telephone answering service, originally scheduled to be installed in time for the first term, was not delivered until the end of that term and had to be postponed for use in the following term.

Instructional Interaction Sessions. In order for students to be able to meet and interact with the course instructor and with the other students in the course, three interaction sessions were held during the term. These sessions were held on campus on designated Saturdays. The sessions were used primarily for lectures, group learning activities, formal testing, and to provide an opportunity for the student to ask questions and to get to know the other students. Program staff members assisted the instructors when necessary, serving as proctors or discussion leaders.

When a student could not attend one of these interaction sessions, as appointment was made with the instructor to enable the student to make up any test missed, and to provide him/her with relevant information discussed at the session. Special reports on the interaction sessions were sent to absentees.

Specific Characteristics of the Four Types of Instructional Delivery Models

Each of the four instructional packages had some type of written materials ranging from reading lists and summaries to highly-structured explicit learning modules. At the same time, each contained components that were unique. The following is a brief description of each delivery model and its packaging format. (See Table 1 for components of the various packages.)

Type I- Television with Supplementary Materials. One of the five initial courses, Law and Morality, was composed of televised lectures and presentations offered through the Sunrise Semester along with supplementary books and instructor-written lectures which were designed to assure that the student was presented with all the materials necessary in order for him to meet the course objectives.

Delivery Type	Course Guide						Unit Components										Evaluation		
	Introduction	Course rationale	Terminal objectives or goals	Study directions	Interaction schedule	Instructor Contact	Rationale	Learning Objectives	Prerequisite objectives	Hierarchy	Study Guide(s)	Test-like questions	Self-scored test items with answer key	Readings	Instructor-written overview or lecture	Self-scored posttest	Pretest	Other Exams	Posttest
TYPE I-Television with supplementary materials (Law and Morality)	x	x		x	x	x	x	x			x	x		x	x			1	1
TYPE II-Programmed Instruction with supplementary readings & materials (Economics)	x	x	x	x	x	x	x	x			x			x				2	1
TYPE III-Reading lists with summaries & supplementary materials (History)	x			x	x	x					x	x		x					1
TYPE IV-Structured materials based on PIC (Curriculum & Supervision)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	1	x	1

TABLE 1

Packaging Format for each of the Four System Types

The student was presented with material initially designed to be supplementary to the televised presentations. During the design stages of the course, it was expected that the production center would forward detailed information concerning the topics and information to be presented on the televised lecture series, as this information had been requested during the initial stage of development. The information actually received, however, was less than adequate for use as a basis for the design and development of a well-organized course in Law and Morality and it was soon realized that the televised lectures would have to serve as supplemental content and that the instructor would have to develop and present materials which would provide the student with the information necessary for meeting the objectives of the course. The Sunrise Semester lectures did, however, provide the student with another frame of reference for the course and offered contact with the general content area.

Type II - Programmed Instruction with Supplementary Readings and Materials. A second type of delivery model, represented in the Introduction to Economics course, was based upon a programmed textbook with supplementary readings and materials. This supplementary reading consisted of a textbook which accompanied the programmed text. There were no instructor written lectures specifically designed to meet the stated course objectives.

This course depended almost entirely upon previously compiled textbooks and required a minimum of developmental time for the instructor since only a few instructor "handouts" were prepared. The instructor's greatest task, in this case, was to organize specific assignments and statements of objectives.

Type III - Reading Lists with Summaries & Supplementary Materials. A third type of model was pilot tested in a History course entitled "The Decline and Fall of Modern Europe," offered by the UESP Program. This course consisted of thirteen books which the students were required to read, plus instructor-written summaries and study questions. The answers to these questions were not mailed in by the students and were not self-graded so that students received very little feedback on their progress, other than that received at the interaction sessions, before being required to take the final examination.

Type IV - Structured Curricular Materials Based Upon a Process Model for the Individualization of Curricula. This course in Curriculum and Supervision was based upon a process model for the design and development of curriculum developed at the Learning Research and Development Center at the University of Pittsburgh. This is a highly developed research-based model representing a process for individualizing curricula through structured materials.

This is the most highly structured of the courses offered as it is based upon a specified model for curriculum development. It is very explicit in terms of student objectives and student procedures. The course provides a pretest for identifying the knowledge which the student may already have, and offers alternatives within the curriculum for meeting the individual goals of the student; for example, students are directed to certain readings if they are not interested in that particular area. The curriculum attempts, first, to provide the student with the knowledge and skills necessary for branching out into specific areas, and then to provide alternative content so that he can apply the knowledge and skills to his own field of interest. In addition, the student is provided with a means for evaluating his own progress through curriculum embedded testing for which answer keys or response criteria are provided which enable him to evaluate his own responses to the criterion referenced test items.

Comparing the Four Delivery Types

Although it is difficult to attempt to compare these different delivery models, since they are within different content areas and are designed and offered by different faculty members, one can examine the similarities or differences among the various types of presentation. As mentioned earlier, all four had a written instructional component. Type I incorporated another kind of medium--television. The major difference, however, among the various kinds of delivery was the degree of structure and specificity. While the History course, Type III, offered minimal structure in presenting the student with a book list and some general direction, the Curriculum and Supervision course presented the student with specific objectives and step-by-step procedures for achieving those objectives. The televised Law and Morality course and the programmed Economics course offered some degree of structure--more than the History course but less than the C&S course.

The only other major difference among the four instructional delivery models is the amount of self-evaluation provided for in the materials The C&S course, Type IV, contains self-scored curriculum embedded test items as well as self-scored posttests. None of the other courses presented the student with so much opportunity to evaluate his own progress throughout the course. The Law and Morality course, Type I, did require the student to mail in answers for case studies presented within the units, but these were faculty graded and served as a partial basis for the student's final grade.

Another means for comparing the courses might be to examine the student performance for each of the instructional delivery systems as a whole. (See Table 2 for student grades.)

TABLE 2

Final Grades for Four UESP Courses

Course	A	B	C	D	F	G*	Total
Law & Morality (Type I)	3	3	2	0	0	7	15
Economics (Type II)	6	13	1	0	0	1	21
History (Type III)	2	5	9	0	0	1	17
Curriculum & Supervision (Type IV)	10	4	3	0	0	8	25
TOTAL	21	25	15	0	0	17	78

*The "G" grade represents an incomplete grade and was administered by mutual agreement between student and instructor to allow the student additional time to complete the course work. This was an alternative to allow for student time flexibility based upon his individual needs and responsibilities.

Student Reaction

Generally, the student reaction to all four types of instructional delivery were positive, with all but one student (a History student) indicating that they would be interested in taking another UESP course if it were offered in their field of interest.

It can be noted that many of the students in the Type I, II, and III courses suggested the addition of components which would lend a greater degree of structure and direction to these courses. Statements such as "Not knowing what points the instructor is stressing," "more sessions to help me correlate the ideas and information into a pattern," "I feel we need more direction," etc. indicate that these students were somewhat confused as to the direction in which they were supposed to progress with the materials. In courses which did not offer instructor-written materials (Type II especially) many students commented on the need for this type of communication. Since these students do not have the opportunity for classroom lectures, where they could pick up such things as instructor emphases and points of special interest, this information seems to be greatly appreciated within the course materials. These kinds of cues assist the student in identifying learning objectives and testing points and are in that sense an important learning aid.

Many of the students indicated that a major advantage to this type of study was that they could study when and where they wished and they always had the materials on hand for review when necessary. The Law and Morality (Type I) students, however, did not have this convenience with the televised lectures since they were presented only once and there was no alternative time schedule. This proved to be disturbing and inconvenient to some of the students as indicated by comments on their course evaluation sheets.*

Faculty Reaction

As a rule, the individual faculty members seemed confident that the students had met the course goals (implicit or explicit), although they recognized weaknesses within their own types of instructional delivery. The History professor, for example, noticed that his students seemed to request additional direction and at one point commented that he had been asked to hold an additional interaction session to assist the students. All of the faculty members seemed to recognize the value of some of the structured components for the packaged materials. They recognized that, for the external studies student, a certain amount of direction must be present within the materials since they are required to meet certain course goals.

---

*For purposes of program evaluation, the student was asked to fill out course rating sheets (2), as well as unit rating sheets and background information forms.

Resources

In examining these four alternative formats, it is necessary that attention be given to the management effort and costs expended in developing and offering each course. Although it is not possible to specify the "real" cost of each course, an assessment can be made which indicates the relative cost of each course in terms of UESP costs, faculty effort, commercial development cost and student costs. These relative costs are presented in Table 3.

TABLE 3

Relative Distribution of Costs by Course

Course	UESP	Faculty Effort	Commercial	Student Costs
Law & Morality (Type I)	Moderate	High	High	Low
Economics (Type 2)	Low	Low	Moderate	Low
History (Type 3)	Moderate	Moderate	High	High
Curriculum & Supervision (Type 4)	High	High	Low	Low

UESP costs refer to those costs that are associated with providing technical developmental assistance to the faculty, production costs, and the general administrative support required to coordinate and manage the course. Since the Curriculum Design course based on the structured-curriculum model involved the greatest volume of technical material, it required the greatest amount of UESP resources. At the other extreme, the utilization of commercially available programmed instructional materials and supplemental textbooks required only a minimal amount of UESP resources. The amount of faculty effort required to develop the individual courses corresponds to the same distribution as that of UESP costs. The structured-curriculum course required an extensive amount of faculty time equivalent to approximately four or five man months of development. Commercial development costs refer to the relative commercial cost that have to be expended to develop the materials. Naturally, the courses utilizing television and textbook supplements are very expensive because of the television production costs. Also, the course requiring thirteen textbooks had high commercial development costs associated with it. These commercial development costs are important to recognize since, if such developmental costs were not assumed by another agency, they would have to be assumed by the Program. In some instances, this could be very prohibitive. Finally, it is important to consider the cost to the student in acquiring the necessary instructional materials. Since the structured-curriculum model, the programmed instruction, and television modes of presentation were either internally produced or else required only a limited number of commercially available materials, these student costs were relatively low. The lengthly reading list required by the History course resulted in about 50% more student costs.

In summary, based on the cost factors associated with the development of these materials, attention should be given, when possible, to the utilization of commercially developed materials, particularly of the programmed instruction mode. In terms of UESP, the structured-curriculum model has been selected as the primary format mode.

Summary

The advantages in flexibility and accessibility of written instructional materials was re-emphasized throughout this attempt to try the various types of instructional delivery systems, as were the limitations and possibilities of television as an instructional medium. A value, in terms of explicit student direction and student self-evaluation, was recognized in the highly-structured curriculum. It seems apparent throughout this study that written materials can provide the external studies student with the information needed for meeting the objectives of a course and that these materials can be supplemented with other media or can be used exclusively by the student. It was also recognized that, in order to address individual student needs and provide instructional alternatives to meet those needs, this Program should continue to experiment with various types of packaging and with various media.

It can be noted here that the structured-curriculum process (Type IV) is recognized to be extremely adaptable to this kind of experimentation since it provides a process for identifying student needs (in terms of a learning hierarchy and structured pretest) as well as a process for identifying appropriate use of media based upon the characteristics of the student population, and the type of objective to be achieved. This kind of instructional delivery system, then, is seen to be extremely useful in maintaining student direction, specificity, and accessibility while at the same time allowing for the individuality and creativity of the instructor in attempting to make use of other media and methods in his course design.

Future Developments

Although the University External Studies Program has achieved some degree of success during its initial stage of operation, the staff of this Program feel that alternative instructional formats need to be considered in order to provide a comprehensive learning system that will most adequately meet the needs of its students. At the present time, the structured-curriculum model is viewed by the staff as having a high degree of potential for formatting the materials, however, the emphasis on paper/pencil presentation needs to be further examined.

In order to systematically examine additional delivery modes, two studies are currently under consideration. The first of these utilizes audio cassettes. Because audio cassettes are readily available at a reasonable cost, the use of them seems to be of some merit. The audio cassette would permit the student the option to hear a discussion representing various points of view about a given topic, to have faculty summaries prepared on given aspects of the course, or could be used as a communication device between faculty and students in terms of answering a student's specific questions. At the present time, audio cassettes are being considered as supplemental components of the instructional package and not as the primary program.

Another system also being considered is that of cable casting; that is, the use of broadcasting systems via a cable television network. On the assumption that the growth of this industry will continue at the same rate it has over the past five years, it appears that a network of cable stations could provide low cost distribution to a large number of households. This program would involve both the written materials already prepared by

UESP and cable casting. The instructional package would consist of a paper/pencil instructional workbook based on the structured-curriculum model, three interaction sessions per term, and fifteen one-hour television presentations per term. Each television presentation would be presented three times in a given day--once a week; morning, afternoon, and evening. Therefore, the student would have available three alternative instructional learning modes: the interaction sessions, the televised presentation, and the paper/pencil presentation. Cable casting would permit flexibility through offering three presentations of a given lesson at various times in the day and would provide a motivational factor in that there would be an implicit pacing for the student because of the scheduled television presentations. In addition, it would be possible to reach a larger number of individuals who cannot currently utilize present educational opportunities.

It is hoped that by systematically examining various types of alternative formats in instructional delivery systems, it will be possible to devise a comprehensive instructional system that can be utilized to meet the needs of non-resident students.

A Computer Word Problem Program designed by Nicholas Laudato during his internship. This is to be published by the Learning Research and Development Center.

COMPUTER ASSISTED INSTRUCTION
IN PROBLEM SOLVING:
THE WORD PROBLEM PROGRAM

Nicholas Charles Laudato

Learning Research and Development Center
University of Pittsburgh

Summer 1973

The research reported herein was supported by a grant from the National Science Foundation (NSF-GJ-540X) and by the Learning Research and Development Center, supported in part as a research and development center by funds from the National Institute of Education (NIE), United States Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position or policy of the sponsoring agencies and no official endorsement should be inferred.

> Why word problems? I hope that I shall shock a few people in asserting that the most important single task of mathematical instruction in the secondary schools is to teach the setting up of equations to solve word problems. Yet there is a strong argument in favor of this opinion ... In solving a word problem by setting up equations, the student translates a real situation into mathematical terms: he has an opportunity to experience that mathematical concepts may be related to reality, but such relations must be carefully worked out. Here is the first opportunity afforded by the curriculum for this basic experience.
>
> -Polya: Mathematical Discovery

INTRODUCTION

The area of arithmetic and algebraic word problems generally presents the elementary school student with his first experience in utilizing mathematics as a tool to solve "real" or physical problems. It is an area which is crucial to the students' later mathematical development and thus comprises an important part of the mathematics curriculum. Word problems have, however, continually frustrated educators' efforts to effectively teach competency in them. This paper describes an attempt to deal with word problems in the elementary school.

The Word Problem Program has been undertaken as one of several programs developed to investigate Computer Assisted Instruction in Problem Solving as part of the Oakleaf Small Computer Project. The Oakleaf Small Computer Project was initiated by LRDC in 1969 under sponsorship of the National Science Foundation. Its principle purpose was to "... investigate appropriate and effective uses of the computer in an individualized school in order to foster the adoption of individualized systems of elementary education ..." (Glaser and Cooley, 1972). The Word Problem Program is also related to IPI (Individually Prescribed Instruction) Math in that one of its goals is to complement the IPI treatment of arithmetic word problems. The fundamental goal of the Word Problem Program, however, as with all other programs in the Computer Assisted Instruction in Problem Solving Project, is to teach elementary school students some generalizable problem solving skills. This goal will be discussed in detail in section 1.

This paper considers the literature pertaining to word problems in both the traditional and computer based modes. On the basis of relevant research, theory, and intuition, the paper then proposes some instructional strategies and methods, as well as a format for a computer program to teach the process of solving word problems.

The paper also hypothesizes relationships between some variables present in word problems and the difficulty of the word problems. Finally, the paper concludes with some sample protocols of an experimental version of the Word Problem Program in operation.

OBJECTIVES OF THE PROGRAM

The fundamental goal of the Word Problem Program is to teach students who use it skills which will make them more effective problem solvers. All of the instructional objectives of the program are derived from this goal, and specific instructional decisions are made on the basis of it. Thus, the program is concerned with teaching not only the skills involved in solving arithmetic word problems, but also skills applicable to a wider range of problem solving situations. This section delineates the cognitive objectives of the program dealing with both of these areas and also describes the affective goals of the program. Before proceeding with this task, however, we must first clarify the meanings we attach to the terms "problem solving" and "word problems".

Several educators have made hypotheses and conclusions regarding the nature of problem solving. It may prove enlightening to consider some of these here. In general terms, John Dewey described a problem as anything that perplexes and challenges the mind so that it makes belief uncertain. Kramer (1966) expands on that basic definition and specifies that the individual who is faced with a problem must "analyze the situation, gather facts that point toward a solution, decide which of those facts are pertinent to the problem, and then, by reasoning logically with these data at hand, make an intelligent choice that terminates his confusion."

Polya (1954) states that the principle parts of a problem are the data, the unknown, and the condition which links the unknown to the data. The task of the problem solver is then to (1) "understand" the problem, i.e., to specify the unknown, the data, and the condition, (2) to plan a solution to the problem, i.e., to find the connection between the data and the unknown, (3) to carry out the plan and (4) to examine the solution obtained and determine if the condition has been met.

A distinction made by Kramer further clarifies the concept of problem. Kramer states that a given situation can be either an enigma, a problem, or an exercise, depending upon the "mathematical maturity" of the individual involved. Thus, a one-step addition open number sentence (e.g., ? + 3 = 9) is an enigma to the three-year-old who cannot understand the question;

a problem to the six-year-old who understands the question but cannot automatically respond; and finally, an exercise to the eleven-year-old who can answer immediately. Gagne (1966) makes a similar distinction. He uses the term "productive problem solving" to refer to "... the finding of solutions to novel problems and should be carefully distinguished from an undesirable use of the term referring to routine substitution of numerical values in mathematical expressions of the same type - a kind of "drill".

The above statements give a general impression of the nature of problem solving tasks. The remainder of this section further elucidates the topic of problem solving in the context of the Word Problem Program and specifies some of the overall objectives of the program. The three subsections deal with arithmetic word problem objectives, general problem solving goals, and the affective goals of the program.

I. Arithmetic Word Problem Objectives

The problems that will serve as our stimuli are verbal quantitative problems, i.e., problems which present the individual with "a described situation that involves a quantitative question for which the individual has no ready answer" (Kramer, 1966). The range of difficulty we intend to cover can be illustrated by the following objectives:

- Given addition and subtraction word stories, the student writes the number sentence. LIMIT: sums to 9 (IPI Math Objective 10-A)
- Given a word problem for which multiplication is the appropriate operation, the student writes a corresponding multiplication fact and writes the answer with the appropriate label. LIMIT: two one-digit factors (IPI Math Objective D - MULT - 2)
- Given a word problem that requires addition, subtraction, or addition and subtraction, the student solves the problem and writes the answer with the appropriate label. LIMIT: four addends per problem, six places per problem, whole number parts to thousands, decimal fraction parts to millionths. (IPI Math Objective F - ADD/SUB - 4)

- Given a word problem that requires from 3 to 5 steps and the application of exactly two operations, the student solves the problem using a calculator and writes the answer with the appropriate label.

This range will include and transcend the objectives referring to word problems currently in IPI Math. Behavioral objectives and learning hierarchies which specify exactly what this entails are left until a later date. The success of the Program in attaining such objectives will be evaluated in the following manner:

Objective 1: We expect students utilizing the program to score significantly higher on Curriculum Embedded tests than controls using the IPI approach.

Objective 2: We expect students utilizing the program to score significantly higher on Post tests than controls using the IPI approach.

Objective 3: We expect students utilizing the program to score significantly higher on word problem sections of IPI placement tests administered in the succeeding year than controls using the IPI approach.

Objective 4: We expect students utilizing the program for two years to place out of significantly more word problem objectives than controls using the IPI approach.

Objective 5: We expect students utilizing the program to score significantly higher on the word problem sections of standardized achievement tests administered at the end of the year.

We also expect students to develop skills which will increase their competency in solving arithmetic and algebraic word problems of a more general nature. We strive to make it possible for many arithmetic situations which are now "enigmas" to become "real" problems to elementary school children. Thus, a major goal of the Word Problem Program is to develop in the student effective problem solving strategies which we expect to transfer to other more complex word problem situations. As a measure of the success of the program in fulfilling this goal, students utilizing the program are expected to score significantly higher on special tests of "more advanced" word problems than controls using the IPI approach. The term "more advanced" refers to problems which are, by some criteria, above the level of experience of the particular student involved and for which no instruction has been received. For example, the tests may consist of problems requiring more steps and/or operations, and a greater degree of structural complexity than those of the highest level that the student has mastered. The students will also be given problems which contain numerical values of a greater magnitude than they are accustomed and asked to specify the correct operations to be used.

II. General Problem Solving Goals

In addition to teaching competency in solving arithmetic word problems, the program is also intended to develop skills in general problem solving, i.e., to develop general skills and strategies whose application is not limited to the specific case of arithmetic word problems. Such general skills are hypothesized to exist by Olton (1969). "They are general cognitive abilities, such as the production of original ideas, the invention of a unifying principle which integrates several disparate events, and the use of various strategies when one is 'stuck' on a complex problem."

In order to specify the nature of the aforementioned skills, a more precise definition of the term "problem" should be presented. Newell and Simon (1972) state that "a person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it." The desired "object" may be something tangible, concrete or abstract, it may be specific or general, and it may be physical or symbolic. The series of actions he should perform can be physical, perceptual or purely mental activities. In particular, the problems which concern us in the Word Problem Program have the following characteristics:

1. They are verbal representations of concrete, physical situations.
2. The task may involve the representation of concrete data in symbolic fashion.
3. The actions required by the problem solver to attain the solution involve mental activities.
4. No specific algorithm exists (applicable to the general problem solving situation) to produce the solution. Productive general strategies do exist, and the learner's ultimate task may be to find one.

5. There is only one solution to the problem, but several paths may exist to the solution.
6. The problem may involve sub-problems which must be solved to reach the final solution to the problem.
7. The environment provides feedback as to the relative tenability of a given step in the solution process.
8. The environment provides the opportunity to test the tenability of the final solution to the problem.

The above list of characteristics represents our operational definition of a problem. The goals of the program are thus derivative from this definition. The goals are:

GOAL 1: We expect students using the Word Problem Program to develop the skills necessary to solve problems as defined above. Some of these skills are listed here. These are taken primarily from the work of Roman (personal communication):

1. Recognizing the existence of a problem and clearly stating the goal.
2. Recognizing, recording, and organizing the given data.
3. Determining if analogous problems have been solved and, if a general strategy or algorithm exists, recalling and applying it.
4. Breaking an apparently complex problem into manageable subparts and solving each part.
5. Reintegrating and substituting the subsolution(s) into a final solution for the problem.
6. Creating hypotheses that are reasonable, consistent with all given data, and testable.
7. Devising tests for the current hypothesis and integrating the evidence from those tests into the next hypothesis.
8. Recognizing when the solution has been attained, or recognizing when help is needed, or recognizing when to give up.
9. Communicating to another about the problem and the attained solution.
10. Extending the solution of a particular problem to a more general problem situation.

GOAL 2: We expect students using the program to develop important mathematical concepts such as those of variable, transitivity, and substitution. Some specific examples of this are given in sections 4 and 5.

GOAL 3: We expect the program to serve as an introduction to algebraic concepts, reasoning, and manipulation of symbolic quantities.

The evaluation of the success of such goals is difficult since few objective measures of such cognitive abilities are available. One group of tests which may prove helpful here are those developed by the Wisconsin Research and Development Center for Cognitive Learning. A goal of their project was to identify and develop tests to measure basic concepts and cognitive abilities. We thus expect students using the Word Problem Program to score significantly higher on these tests than controls.

III. Affective Goals

The specification and evaluation of affective goals presents an even greater problem than that of the general problem solving objectives. Krathwohl et al (1956) define affective objectives as those which emphasize "a feeling tone, an emotion, or a degree of acceptance or rejection." Such objectives are generally expressed as "interests, attitudes, appreciations, values, and emotional sets or biases." The statement of these objectives in specific behavioral terms is, however, exceedingly difficult. Subsequently, since tests for the attainment of objectives involve measurements of the presence of certain behaviors, evaluation is even more difficult. At present, it is not our intention to deal fully with these problems and thus the remainder of this section is devoted to an overview of our current thinking.

We are interested in the program users' behavior in three areas:

1) toward the Word Problems Program, i.e.,towards instruction via the program as opposed to textbook, booklet, or class,
2) towards arithmetic word problems as compared to other subject areas, interests, and activities and,
3) toward problem solving in general.

The affective goals of the program are:

GOAL 1: In each of the above areas, we expect all program users to behave at Krathwohl's level of (1.2) willingness to receive, i.e.,all users should be disposed towards (willing to tolerate and not avoid) the three areas.

GOAL 2: We expect at least 2/3 of the users to attain behavior at some level of "responding". This includes:

(2.1) Acquiescence in responding: The user is active in responding but passive in terms of the initiation of behavior to the three areas.

(2.2) Willingness to respond: The user voluntarily chooses to engage in activities within the program and in problem solving.

(2.3) Satisfaction in response: The user's behavior in the three areas is accompanied by "a feeling of satisfaction, an emotional response, generally of pleasure, zest, and enjoyment."

GOAL 3: We expect a minority (approximately 1/4) of the users to attain behavior at some level of "valuing". This includes:

(3.1) Acceptance of a value: The user is motivated towards activities in the three areas stimulated by a "belief" that these activities have some worth or value.

(3.2) Preference for a value: The user not only accepts the value of activities in the three areas, but actively pursues such activities.

(3.3) Commitment: The user is motivated to action based on a "conviction" that the three areas have value.

There will be no directed effort to inculcate these attitudes, appreciations,and values. Rather, we expect the program itself to provide sufficient reinforcement for the attainment of these goals. Furthermore, these are primarily long range goals in that we do not expect many of these goals to be met within the first year. Instead, they are expected to be met at various points along a user's history.

Finally, evaluation of the success of these goals can consist of two types of activities:

1) direct observation of user behavior by teacher and/or experimenter and
2) user performance on specially devised tests (based on Krathwohl's taxonomy) to measure the presence of these behaviors.

Both of these methods, however, have disadvantages. The first involves a great deal of time and the possibility of lack of control and experimental bias. The second involves the creation of a test whose validity would be subject to careful scrutiny. Thus, the decision regarding exactly which method(s) to utilize has not been made at this time and will be postponed to a later date.

RESEARCH IN WORD PROBLEMS

Research in arithmetic word problems has been conducted in a number of diverse settings and with a variety of different objectives. Studies have been made on: 1) affective variables and individual differences, 2) student skills, abilities, and methods, 3) instructional techniques, strategies, and methods, and 4) structural variables hypothesized to affect word problem difficulty. This review will present a brief sample of the research which is relevant to developing a curriculum designed to teach competency in the solution of arithmetic word problems.

A study by Gorman (1967) has proved useful in the process of selecting pertinent research. Gorman collected and critically analyzed all available research on arithmetic word problems conducted from 1925 to 1965. After the preliminary selection of 293 studies, he applied a set of arbitrary criteria and rejected 70% of the studies for failure to meet his requirements. The criteria stipulated that the studies must:

1) pertain to written problems in elementary school mathematics
2) include pupils in some of grades K-6 in the population
3) be conducted between 1925 and 1965
4) report results based on valid and reliable instruments and procedures
5) be available from interlibrary loan, manuscript procurement, microfilm purchase, etc.
6) be the original study (whenever possible)

The remaining studies were then examined for compliance to criteria of internal and external validity, i.e., in order that a study be accepted, it must provide control for every factor which influences internal or external validity. The eight factors (based on Campbell and Stanley, 1963) which affect internal validity are: history, maturation, testing instrumentation, regression, selection, mortality, and the interaction of selection and maturation, history, testing, or mortality. The external validity was evaluated according to the interaction of testing and the experimental variable, selection biases and the experimental variable, reactive effects of the experimental variable, and multiple treatment effects. After this final analysis, 37 studies were accepted.

The Gorman study was used as a tool in selecting and evaluating relevant research. Unless otherwise noted, the studies reported here from 1925-65 are those accepted by Gorman. The studies are listed by topic.

I. Student Skills

Balow (1964) investigated the relationship of reading and computational ability to problem solving ability. As measures of these abilities, he used three subtests of Stanford Achievement Tests: Word Meaning and Paragraph Meaning, Computation, and Reasoning. The study was performed on 468 children chosen from a group of 1400 sixth graders. Balow found that:

1) Both general reading ability and computation ability have an effect on problem solving ability. Controlling I.Q. drastically reduces the strength of the relationship.
2) For a given level of computation ability, problem solving ability increases as reading ability increases, and for a given level of reading ability, problem solving increases as computation ability increases.

Gorman sites four other studies which examine such relationships and summarizes them as follows:

1) Factors most closely associated with success in problem solving are those related to numbers and reasoning while factors least closely related pertain to vocabulary and reading abilities. (Hansen, 1943)
2) Ability in fundamental operations and tests of problem reading (or problem analysis) have a higher correlation with tests of problem solving than do tests of general reading. (Stevens, 1932)
3) Even though intelligence and computational ability are factors that cause differences in problem solving performance, other variables are also evident. However, reading ability as measured by achievement tests is not an important factor in problem solving ability. (Engelhart, 1932)
4) A complex interaction prevails between reading comprehension, reasoning, process selection, computation, and problem solving. (Martin, 1963)

Riedesel also reviewed the literature on elementary school education in Mathematics. On this basis, he identified eight factors which are associated with high achievement in problem solving. The factors were: intelligence, computational ability, ability to estimate answers, ability to analyze problems, arithmetic vocabulary, ability to use quantitative relationships that are social in nature, ability to note irrelevant (superfluous) detail, and knowledge of arithmetic concepts. He sites seven research works in support of this conclusion.

II. Instructional Methods

Research on instructional techniques and methods of teaching competency in solving word problems has traditionally consisted of making comparisons of the effectiveness of two or three methods. It seems, however, that every researcher has a different concept or operating definition of the exact nature of those methods. For example, the term "Formal Analysis Method" has been used to refer to a three, four, five, or six step method of analysis. Since the authors are not always explicit in their definition of terms, one is forced to infer the treatment used in order to attain any useable and comprehensible comparison. In this section, research is grouped according to method.

The methods shall be defined as follows:

1) Practice-Only. This method appears under many different names in the literature primarily as a control method. It is, however, rarely defined explicitly and several variations can be seen to exist. The definition that seems most applicable is that which Morton (1925) calls the "Individual Method" in which the students are presented problems and left "to their own devices" (in Horsman, 1940).

2) Vocabulary Methods are methods which attempt to improve the student's ability to solve word problems by instructing him in (usually specialized) vocabulary.

3) Morton defines the Analogy Method as follows:

> The pupil is given an easy oral problem which is similar to a difficult written problem. It is presumed that the pupil can solve the easy oral problem, see the analogy to the difficult written problem and then be able to solve the latter.

4) Morton (1925) defines the Dependencies Method (or the Method of Graphical Analysis) as follows:

The pupil is taught to diagram the procedure to be followed. He begins by determining what is to be found,then observes that this depends upon the data that are given in the problem, that these data depend upon others, and so on until the diagram has been completed. This diagram is intended to assist the pupil in outlining his thought procedures. It emphasizes relationships directed toward the solution.

5) The Formal Analysis Method

Several variations of this method are also in existence. For example, Morton defines it as a three step analysis of the problem, whereas Washburne and Osborne (1925) consider it a six step process which includes a step directing the student to estimate the magnitude of the result. All definitions, however, include the following steps as crucial to the analysis: (1) Determine what is to be found, i.e., specify the unknown, (2) determine what information and numerical data are given in the problem, and (3) decide which processes (operations) are necessary to attain the solution.

6) Other Analysis Methods

The sixth classification includes analytical or quasi-analytical techniques other than that of Formal Analysis.

The results of the research on instructional methods are summarized according to each of the aforementioned methods. Under each method, the research is divided into categories on the basis of the methods' superiority, inferiority, or lack of significant differences to other instructional methods. Thus, the reader can quickly refer to any method and gain insight into its comparison to other methods. This, of course, necessitates some duplication under each method.

1) Practice-Only

i) The Practice-Only method was found to be superior to the following methods:

- the Formal Analysis method in a study by Hanna (1929, reported in Horsman). Hanna called Practice-Only the "Individual Method".
- (Formal) Analysis by Washburne and Osborne in 1926 (not reviewed by Gorman). In this study, the Practice-Only method was referred to as the "Many Problem" method and was considered to be "decidely the most effective method of all."

- the Analogy method by Washburne and Osborne.
- the "meaning" or "insight" method for students of relatively low intellectual ability and high achievement in a study by Anderson (1949, reported in Gorman). In this study, Practice-Only is called the "Drill Method". Gorman does not define "the meaning method."

ii) The Practice-Only method was found to be inferior to the following methods:

- the method of providing "systematic instruction" in the fundamental processes in a study by Pace (1959) reported in Gorman. Systematic instruction was defined as a process in which students "are asked to explain how a problem is to be solved and why a particular process is appropriate".
- the Wanted-Given method (see Other Analysis methods) by Wilson (1964) reported in both Gorman and Jerman (1971).
- the Vocabulary Method by Vanderlinde (1962, in Gorman). It is presumed that the term "control method" refers to Practice-Only.
- the "meaning" method for pupils of high intellectual ability and low achievement by Anderson (above).

iii) No significant differences were found between the Practice-Only method and the following methods:

- the Dependencies method by Hanna
- a technique which encouraged students to estimate their answers before seeking the solution in a study by Dickey (1934, in Gorman).
- the Action Sequence method (see Other Analysis methods) by Wilson.
- a modified Wanted-Given program (see Other Analysis methods) by Jerman (1971). It is again presumed on the basis of the report that the "non-treatment" groups engaged in Practice-Only.
- The Productive Thinking Program (see Other Analysis methods) by Jerman.

3) Vocabulary Methods

i) A vocabulary method was found superior to the control method (presumably Practice-Only) by VanderLinde. VanderLinde used the "direct study" technique of studying quantitative vocabulary which enabled the child to "establish a three-way association between the written symbol, the sound of the term, and at least one of its meanings." He found that students who had used this technique achieved significantly higher scores on a test of "arithmetic problem solving and concepts."

ii) a vocabulary method was found inferior to an Analogy method by Theile (1939, reported in Gorman). The vocabulary method involved the completion of mathematical problems with the correct term.

3) Analogy Methods

i) Analogy methods were found superior to the following methods:

- a step-by-step (Formal) analysis method by Theile. Theile used "the association method, or that technique by which difficult or incorrect problems are associated with a model."
- a Vocabulary method by Thiele

ii) The Analogy method was found to be inferior to the following methods:

- (Formal) analysis for the lower half of the children in a study by Washburne and Osborne. They state that Formal Analysis is "decidedly superior."
- the "Many Problem" technique (Practice-Only) by Washburne and Osborne.

iii) No significant differences were found between the Analogy method and Formal Analysis for the superior half of the children in a study by Washburne and Osborne. They state that "training in the seeing of analogies appears to be equal or slightly superior to training in formal analysis for the superior half of children."

4) The Dependencies Method

i) The Dependencies Method was found to be superior to the following methods:

- the "Conventional-Formulae" (Formal Analysis) method by Hanna.
- the "Individual Method" (Practice-Only) for the lower third of the students used by Hanna.

iii) No significant differences were found between the Dependencies method and the following methods:

- Practice-Only by Hanna
- Formal Analysis in a study by Horsman (1940)

5) Formal Analysis

i) The Formal Analysis method was found to be decidedly superior to the Analogy method by Washburne and Osborne when only the "lower half" of the subjects were considered.

ii) The Formal Analysis method was found to be inferior to the following methods:

- the "Individual Method" (Practice-Only) by Hanna
- the "Many Problem" (Practice-Only) method by Washburne and Osborne
- the Association (Analogy) method by Theile
- the Dependencies method by Hanna

iii) No significant differences were found between the Formal Analysis method and the following methods:

the Analogy method when only the superior half of the subjects are considered by Washburne and Osborne

- the Dependencies method by Horsman

With regard to the literature on the Formal Analysis method, Suydam and Riedesel (1969) report evidence from five other studies which support their conclusion that "informal procedures are superior to following rigid steps .... If this analysis method is used, it is recommended that only one or two of the steps be tried with any one problem."

6) Other Methods of Analysis

Wilson (1964, in both Gorman and Jerman) compared the effectiveness of three instructional procedures: the Wanted-Given, Action Sequence, and Practice Only methods. The Wanted-Given program:

> focuses on the goals and "tools", the "why" and "with what", the ends and means, the wanted and givens in situations from which the meaning or "attributes" of an operation is to be abstracted. This program emphasizes "why" and "with what" one adds, subtracts, etc. Hence, the operations are conceived of in terms of their characteristic ends-means. Or, in other words, the operations are relationships, or have structures, the rational attributes of which are wanted-givens.

In the Wanted-Given approach, the subjects are instructed to:

(1) recognize the wanted-given structure of the problem

(2) express this structure as an equation

(3) compute by using the operation indicated by the equation.

As an example, the problem

> Bob had 9 marbles. Dick gave him 3 marbles. How many marbles did Bob have then?

was classified as "a problem in which the size of a total is wanted and the sizes of its parts are given" and the Wanted-given structure of addition is recognized. The child must then solve the appropriate equation (9 + 3 = n or n = 9 + 3). The problems used in the study were all one step, one operation word problems and the equations referred to in (2) were to be of the "direct" type, i.e., with the unknown isolated on one side of the equation.

The Action-Sequence method is described (in Gorman) as a program

> focusing on what is going on, what events went on, what is being done, what is done, what was the sequence of events, etc., in situations from which the meaning or "attributes" of an operation is to be abstracted. This program emphasizes what one does mentally or physically when one is adding, subtracting, etc. Hence, the operations are conceived of in terms of their characteristic action-sequence. In other words, the operations are relationships, or have structures, the relational attributes of which are action-sequences.

In the Action-Sequence approach, the directions were:

(1) 'see' or recognize the real or imagined action-sequence structure of a problem.

(2) express the action-sequence in an equation.

(3) compute, using the operation indicated if the equation is direct; if the equation is indirect, imagine an appropriate second action sequence, express it as an equation and compute using the operation indicated.

(4) check by rewriting the equation with the answer in the proper position.

Wilson found that the Wanted-Given program produces statistically significant improvement in verbal problem solving ability over both the Practice-Only and the Action-Sequence methods. He failed to attain significant differences in favor of Action-Sequence over Practice Only.

Jerman (1971) performed a study which compared the effectiveness of The Productive Thinking Program, a Modified Wanted-Given program and a control group. The Productive Thinking Program is a commercially available series of programmed comic books in which children learn to solve problems by following the exploits of a brother-sister-uncle trio. The program is designed to promote the generalized problem-solving skills of elementary school students. Jerman summarizes the program's purpose as follows: "to develop and strengthen a student's ability in using important skills and strategies for thinking and problem solving, to improve a student's awareness of his own thinking processes, and to improve his attitude toward activities that involve use of the mind."

The Modified Wanted-Given program developed by Jerman differed from Wilson's program in that it asked the student to progress through a number of steps (dependent on the number of steps in the problem) by making a choice between two alternatives at each step. The problems were identified as either sum- or product-type problems as opposed to the wanted-given whole-part relationship of the Wilson program. Throughout the program, emphasis was placed on the meaning of the terms "sum", "addends" etc. and the number of rules to be learned by the student was kept to a minimum. Finally, the students were allowed (even encouraged) to write indirect number sentences where appropriate and to use these to generate the direct equation and subsequently attain the solution. The results of the study were as follows:

(1) No significant difference was found between scores of students using The Productive Thinking Program and the Modified Wanted-Given program. In a follow-up study seven weeks later, significant results favored the Modified Wanted-given.

(2) No significant difference was found between the treatment and control groups.

(3) A significant difference ($p < .001$) was found between treatment and control groups in the number of correct procedures used by

students to solve the problems. Also, the Modified Wanted-Given favored ($p < .005$) *The Productive Thinking Program* in this respect.

III. Structural Variables

Structural variables are inner- or inter-problem variables whose presence, absence, or magnitude is hypothesized to affect the difficulty of a particular word problem. The most recent studies regarding structural variables have been conducted by Loftus and others at the Institute for Mathematical Studies in the Social Sciences at Stanford University. These have been conducted within the context of a Computer Assisted Instruction Program for sixth grade students. The program was unique in several ways. First, it did not require the students to perform the actual arithmetic computations, but did compel them to indicate the operations and operands in an unusual fashion. It required from four to eight weeks for the students to master the instruction set. Furthermore, the results may not be completely generalizable since the experiment was performed on what Loftus (1970) refers to as "slow learners". Since the implications of the Stanford studies are directly relevant to the present work, a brief description of the format of the Loftus word problem program will be given here.

The program typed a word problem on the printout sheet and followed it with a printout of the numerical data which appeared in the problem on separate, numbered lines. A typical problem from the instruction set follows:

```
27 CHILDREN GOT 13 PIECES OF CANDY EACH.
GENEROUS GEORGIA GAVE AWAY 9 PIECES.
HOW MANY PIECES DID SHE HAVE REMAINING...
G         (1) 27
G         (2) 13
G         (3)  9
```

The "G" indicates that the numbers were given in the problem. In order for the student to perform an operation, he had to specify the line (not the number) and the operation in suffix notation. Thus, to solve the above problem, the student would type *1.2 M* which meant "multiply the number on line (1) by the number on line (2), or 27 X 13".

The results were computed by the program and displayed with the next consequtive line number. To indicate that his answer could be found on a certain line, the student typed 5X, meaning "the number on line (5) is my answer". The student could also enter a new number into the machine (for conversion problems) and be given hints (during the instruction phase), e.g., for the problem "What is (486 + 390) + 707?", the hint is "First find 486 + 390. Then add that sum to 707". The format of the Stanford CAI program, and its effect upon the experimental results, will be discussed in more detail elsewhere.

The results of the Stanford and other studies are presented here according to topic.

1. The Operations variable is defined by Loftus as the minimum number of different operations required to reach the correct solution. Thus, a problem requiring a student to add seven numbers necessitates one operation, whereas a problem requiring the average of three numbers requires two operations. The operation variable can assume only the values 1, 2, 3, or 4. The hypothesis was that the larger the number of operations required, the more difficult the problem. This variable was found to be significant in (Loftus, 1970; Suppes Loftus, and Jerman, 1969; and Loftus and Suppes, 1972).

2. The sequential variable involves the relationships between problems presented in a sequence. The hypothesis was that a problem is easier if it can be solved by the same operations in the same order as the preceeding problem. This variable was found significant by Loftus; Suppes, Loftus, and Jerman; and Loftus and Suppes. The "arrangement of problems within a series" (sequential) variable was also found significant by Hydle and Clapp (1926, a study rejected by Gorman).

3. The depth variable, as defined by Loftus, is a measure of the structural complexity of the sentences within a word problem. Based on a procedure defined by Yngve (1964), a number is assigned to each word in a sentence depending on how "imbedded" the word is in the sentence's structure tree diagram. The mean of these numbers (computed for every word in the sentence) is taken and the measure of "depth" becomes the greatest numerical value of the means of all the sentences within a problem. This variable was found to be significant in studies by Loftus; and Loftus and Suppes.

4. The *length* variable was defined by Loftus as the number of words in the problem. This was significant in Loftus; and Loftus and Suppes; but not in Suppes, Loftus and Jerman.

5. The *conversion* variable was found significant in studies by Loftus; Suppes, Loftus, and Jerman; and Loftus and Suppes. The hypothesis was that problems requiring conversion of units are more difficult than those which do not.

6. The *verbal clue* variable was not found to affect problem difficulty significantly by Loftus; Suppes, Loftus, and Jerman; and Loftus and Suppes. The hypothesis was that problems which contained a verbal clue to the required operation were easier than those which did not. The verbal clues were defined as "and" for addition, "left" for subtraction, "each" for multiplication, and "each" or "average" for division.

7. The *steps* variable was defined by Loftus as the minimum number of steps required to reach the solution. Each application of any operation is considered a step. Thus, a problem requiring a student to add seven numbers requires six steps (only one operation) whereas, a problem requiring a student to find the average of three numbers requires three steps (and two operations). This was insignificant in studies by Loftus; Suppes, Loftus, and Jerman; and Loftus and Suppes.

8. The *order of numerical data* variable refers to the hypothesis that a problem is easier if the numerical data within it are presented in an order in which they can be used to solve the problem. This was found to be true in a study by Burns and Yonally (1964), and was found insignificant in studies by Loftus; and Loftus and Suppes.

9. The *order of fundamental processes* variable was investigated extensively at the University of Pittsburgh by Young and others. Young (1941) had hypothesized that the order in which the fundamental arithmetic processes (operations) occur in problems would affect the difficulty of the problems. To test this hypothesis both Becker (1938), and Berglund-Gray (1938) generated a set of two-step, two-operation problems. The set of problems was divided into six subsets based

on the six possible combinations of four things (the arithmetic operations) used two at a time (addition-subtraction problems, addition-multiplication, etc.). The order in which the processes appeared in the problems was then reversed to generate a second set with all other variables remaining constant. For example, a problem in the first set would be solved by first applying addition and then subtraction, whereas the analogous problem in the second set would be solved by subtracting first and then adding. Berglund-Gray found the "difficulty of interpreting arithmetic problems is definitely affected by the order of occurrence of the fundamental solution process" and summarizes in the following table:

More Difficult	Less Difficult
Subtraction - Addition	Addition - Subtraction
Addition - Multiplication	Multiplication - Addition
Division - Addition	Addition - Division
Division - Subtraction	Subtraction - Division
Subtraction - Multiplication	Multiplication - Subtraction
Division - Multiplication	Multiplication - Division

where "Division - Multiplication" refers to the problem in which division is performed first and multiplication second. Becker had similar findings but did not include all of the cases. Mc Isaac (1940) performed the same experiment on three-step, two- or three-operation problems and found the order of occurrence equally significant.

An important flaw in the above studies is that many of the problems can be solved in an order other than that which the authors assume they will be solved. Also, the process used to generate "identical" problems with a reversed occurrence of operations does not, in reality, control for all other variables. The problems of the reversed sequence are often far more complexly worded than the original. This has the effect of increasing the structural complexity of the problem (the "depth" variable). It should be noted that neither Yngve nor Transformational grammar were available in 1940. Gorman rejected all four of these studies for failure to isolate the experimental variable.

10. The sequence of information of arithmetic word problems was investigated by Rosenthal (1971). Rosenthal generated 32 addition and subtraction word problems based on the following item forms: $m \pm n = ?$ and $? \pm n = p$. Each problem involved the subject "starting out" with "m" objects, gaining or losing "n" objects and ending up with "p" objects. Either "m" or "p" was chosen for the unknown quantity. Three hypotheses were investigated:

(1) There exist significant differences between problems generated from each of the four item forms (which specify whether the unknown is the starting or ending set).

(2) That problems in which information was presented in the forward temporal order would be easier than the reverse. For example, for the "$m + n = ?$" item form, the problem

> If Paul started out with 5 boats and he bought
> 3 boats, how many boats did he end up with?

in which the events are mentioned in their proper temporal sequence will be less difficult than

> How many boats did Paul end up with if he bought 3
> boats,and he started out with 5 boats?

which is stated in reverse temporal sequence.

(3) There will exist significant differences in problems due to differential effects associated with the problem verb.

Significant differences were found for hypotheses (1) and (2), but not for (3).

11. The position of the question was investigated by Williams and McCreight (1965). Their hypothesis was that placing the question at the beginning of the problem will result in significant differences when compared to placing the question at the end of the problem. They found that the problems in which the question appeared at the beginning of the problem were slightly (p .1) easier.

12. Other variables

Hydle and Clapp (1926) investigated some other variables in a massive study involving from 5870 to 7029 subjects. They found that problems with an abstract objective setting (problems containing situations which are difficult to visualize) and those which contain unfamiliar objects, large numbers, symbols, or non-essential (superfluous) information are significantly more difficult than problems which do not contain these variables. Gorman rejected this study because of factors affecting internal validity.

INSTRUCTIONAL METHODS IN THE WORD PROBLEM PROGRAM

In the Word Problem Program, instructional decisions have been made and are currently being made on the basis of mathematical and educational philosophy, educational psychology, the results of research, and on the basis of intuition. Some of these decisions are discussed in this section according to the following scheme:

1. The Sequence of Instructional Objectives:
   This subsection relates the rationale and method of ordering objectives within the program.
2. Instructional Strategies:
   This subsection relates the other teaching strategies employed by the program to meet the objectives.
3. The Role of Computation:
   This subsection relates the rationale behind an instructional decision concerning the relationship of computational ability to problem solving ability.

Later sections of the paper expand upon some topics which appear in this section. These deal with the program format and the relationship of word problems to number sentences.

I. Sequence of Instructional Objectives

In Goals for School Mathematics (1963) the authors state that "...problem material should be considered at least as important as the text proper...we therefore believe that the composition of problem sequences is one of the largest and one of the most urgent tasks in curricular development." In the Word Problem Program, the textual material is virtually eliminated and thus, the manner in which sets of word problems are sequenced will bear the brunt of the instructional load.
The assumption is that a precise ordering of instructional objectives (sets of problems) from easy to difficult (simple to complex) will prove to be an effective instructional procedure.

The use of precise sequences of instructional objectives which form learning hierarchies has been suggested by Gagnè(1968, 1970). Gagnè hypothesized that a given task which was to be learned could be analyzed into simpler prerequisite capabilities. Thus, by successively asking the question "what would the individual already have to know how to do in order to learn this new capability simply by being given verbal instruction?", a list of subordinate capabilities may be identified. The learning of these subordinate tasks should facilitate positive transfer of learning to the learning of the superordinate task, i.e., the superordinate task "will be more readily learned (on the average, throughout a group of students) if the subordinate capabilities have been previously acquired and are readily available for recall."

The implication of Gagnè's work for the Word Problem Program is that sets of problems should be individually analyzed and ordered according to the skills necessary for solution. However, the task of identifying subordinate skills in word problems is more complex than in other areas where this analysis technique has been successfully applied. To verify this statement, one need only examine the research which has been conducted on structural variables in word problems. Such research represents an attempt to delineate factors which contribute to problem difficulty and are therefore thought of as analogous to the skills necessary to complete the problem. As evidenced in the review of the literature, even this simplification of a Gagnè type task analysis is often complex and sometimes yields contradictory results. For this reason, the results of research on structural variables has rarely been utilized directly in the design of curriculum. One of the first to use this method with some degree of success was Gill (1940).

Gill compared the effectiveness of the method of providing fourth and fifth grade students with problems of "graded difficulty" to a control method (Practice-Only). He generated sets of 7 or 8 problems which were given to the students in 26 lessons over two 13 week semesters. Gill ordered the problems by directly applying the results of existing research on structural variables to the task of writing the problems. The variables which had been found to affect item difficulty were individually arranged from easy to difficult along the entire continuum of 26 lessons, i.e., each particular variable was graded on a scale and applied by order of difficulty to the problems in the lesson. All of these variables were then incorporated to write the graded set of problems. The variables which were taken into consideration were:

1. The order of the fundamental processes.
2. The size of numbers.
3. The objectivity (the ease with which a problem can be "visualized").
4. The occurrence of unfamiliar objects in the problem.
5. The arrangement of problems (the Loftus sequential variable).
6. The occurrence of nonessential or superfluous information.
7. The use of symbols in the problem.

Gill found superior achievement in the experimental group on standardized arithmetic tests, a test of word problem solving which did not require arithmetic computations, and a test designed to sample the structural variables at different levels. Gill's study was rejected by Gorman for failure to control the teacher variable (the same teacher did not teach both groups except in two of the 16 classes).

On the basis of the aforementioned theory and of Gill's research, it seems reasonable to assume that a hierarchical ordering of sets of word problems will be an effective instructional strategy. Once the pedagogical decision to hierarchically sequence the word problem objectives has been made, the problem of how to successfully perform this task becomes paramount. This could be accomplished in several ways. It could be done empirically by testing large numbers of children on each problem to be used and subsequently performing the necessary statistical analysis. This method, however, would prove impractical due to the immense numbers of problems which would be involved. A reasonable alternative would be an application of Gill's method based on current research.

In reviewing the literature on structural variables, the Loftus study stands out as being particularly applicable to such an undertaking. In her study, Loftus determined regression coefficients for the eight variables she examined (five of which she found significant). On the basis of the coefficients, a difficulty index can be determined for a given problem by identifying the value of each variable in the problem and plugging these values into the regression equation. A total set of problems could thus be ordered on the basis of the difficulty indices computed for each individual problem.

Unfortunately, it does not appear that the Loftus results will be directly applicable to the ordering of problems in the Word Problem Program. This is due to several factors in the study which cast doubts on its validity and generalizability. The first such factor is the awkward method in which students were expected to respond to the problems. The format, which is described briefly in the review section, was so complex that it required from four to eight weeks for the students to master the instruction set before beginning the (four week) problem set. Secondly, the population consisted of "slow learners" and, hence, may not be completely generalizable.

With regard to the regression equation itself, Loftus states that two particular problems contributed most heavily to the total chi square and that "the regression models investigated cannot account for performance on these two types of problems." In addition, the results concerning two of the eight variables studied can be contradicted by other research. Finally, since other researchers have identified other significant variables, it is clear that the Loftus variables do not take all of the relevant factors into consideration. The nature of the regression equation, precludes its modification to include new variables without a massive amount of work. Consequently, the Loftus results should not be applied as the sole basis for organizing and sequencing the problems in the Word Problem Program.

Several possible approaches to ordering a set of word problems have been considered. As stated previously, the method of treating each of several hundred problems separately and investigating student performance was rejected as impractical. Gill's work was rejected as out of date and the Loftus study was performed in an inappropriate population of students and does not include all significant variables. The classification of all problems on the basis of structural variables is still desirable, however, and the problem thus becomes one of deciding which variables to consider and exactly how to use them. A crucial point to remember is that research on structural variables represents an attempt to deal with the problem solving skills which are required in a particular problem. Thus, the depth variable is presumably significant because of additional skills or concepts which are required of the learner for problems of greater syntactic complexity. It is therefore desirable to choose variables for consideration which are directly related to (hypothesized) problem solving skills. Clearly, variables cannot be ignored if they have consistently proven to be significant in previous research. Other variables must be ignored, either because they have no close relationship to skills necessary to solve the problem or because previous research has shown them to be insignificant. For these reasons, a new variable (or set of variables) is under consideration for use as a major tool for organizing the Word Problem Program objectives. This will be discussed in detail in the section on Number Sentences and Word Problems.

II. Instructional Strategies

The choice of which instructional strategies to employ in the Word Problem Program should be made on the basis of both the objectives of the program and the results of research in the area. The objectives of the program are basically aimed at two goals: The development of skills to increase competency in solving arithmetic word problems and the development of more general problem solving skills. Ideally, previous research should give some indication as to which methods will be effective in attaining these goals.

As evidenced in the review of literature, there is much debate and controversy over the question of whether to teach specific word problem solving strategies or algorithms (and if so, which ones), to teach general problem solving skills, reading skills, or simply to employ the Practice-Only Method. Research has yielded contradictory results as to which methods are more effective. For example, the vocabulary method was found superior to Practice-Only by VanderLinde. Since Practice-Only was found superior to both the Analogy and Analysis methods, then one should conclude that the study of vocabulary would also prove superior to Analogy and Analysis. This was not found to be the case, however, since Thiele,using a different technique, found the Analogy method more effective than the study of vocabulary. Thus, care must be taken in attempting to apply the results of research directly to program development.

Research can, however, prove helpful in the decision as to which methods to employ in the Word Problem Program. Intuitively, it seems logical that to accomplish the program's goals, the program should make use of an Analysis or Analogy method. Presumably, utilization of one or both of these methods would aid in developing problem solving strategies and skills applicable to specific word problems as well as general problem solving situations. Research, however, indicates that the Formal analysis method would not prove effective in teaching competency in arithmetic word problems. As mentioned earlier, Suydam and Riedesel conclude that "informal procedures are superior to following rigid steps...if this analysis method is used, it is recommended that only one or two of the steps be tried with any one problem." This conclusion, along with the favorable reports on the effectiveness of "Other Analysis Methods" which utilize number sentences (Wilson, Jerman), support the method described below for the Word Problem Program.

In the Word Problem Program, a structure of hints available to the student will be used to foster an analytical approach to problem solving. The use of this approach will be encouraged but not demanded and is thus made available at the student's option. When a student is experiencing difficulty with a particular problem, he may type "HINT" and a low level hint will be supplied. Subsequent use of the HINT command will provide additional hints until the final level is reached. The levels of hints are as follows:

0. If the problem is one requiring a conversion of units, the appropriate conversion will be made available.
1. The first level hint will be one borrowed from Polya. In Polya's approach to problem solving, the first step is to identify the unknown. The first hint on the word problem program will thus be a specification of what the student is expected to find.
2. The second hint will consist of a rewording of the problem in simpler (shorter) terms. The rationale here is to reduce the problem to a simpler problem by removing all of the less relevant information. In this sense, it is similar to an analogy method.
3. The final hint consists of a translation of the word problem into a corresponding number sentence. The number sentence will not necessarily have the unknown isolated on one side of the

equation, i.e., it may be indirect.

The intent of the hint structure is therefore to encourage the student to take the following steps in problem analysis:

1. identify the unknown
2. translate the word problem into simplier terms
3. translate the new version into an arithmetic number sentence (or a collection of such sentences) and
4. solve the number sentence(s)

This approach, though analytical in nature, is not a Formal Analysis method. It resembles Formal Analysis in that a step-by-step procedure is encouraged, but it also resembles a vocabulary approach (the translation of the initial word problem), and the analogy method (the student solves the simpler word problem). It is most similar to the experimental programs of Wilson and Jerman (see Other Analysis Methods in the review) in that both of these recognized the role of the number sentence in the solution of word problems. In the Action Sequence and the Wanted-Given programs, the number sentence was seen as a natural representation of the events in any given word problem. In this program, it is seen as a tool, i.e., as an abstraction of the problem situation in a step towards solution. The exact nature of the relationship of the number sentences to the Word Problem Program will be elaborated upon in the next section.

Finally, the manner in which problems are presented to the student and the form in which the student must respond (the program format) is expected to help attain the program objectives and is thus part of the instructional strategy of the program. This will also be discussed in the last section.

III. The Role of Computation

The numeric values in word problems play both a confounding and an undeniably important role. For example, Suydam and Riedesel state that studies "...reveal that pupils often give little attention to the actual problems; instead they almost randomly manipulate numbers." We expect that this is not far from the truth, but tend to believe that such manipulation of numbers is more algorithmic than random. For example, Stevenson (1925) relates a method of word problem solving used by an elementary school student as follows:

> If there are lots of numbers, I add. If there are only two numbers with lots of parts, I subtract. But if there are just two numbers with and one littler than the other, it is hard. I divide if they come out even, but if they don't, I multiply.

Conclusions made on the basis of an analysis of number sentences in the IPI Functions program indicate that similar algorithms are used by children working on number sentences. This will be discussed in detail later along with some suggestions for dealing with the situation.

The research on the sequence variable also seems to support the above arguments. Both Loftus;and Hydle and Clapp found that a given problem is easier if it can be solved by the same operations (in the same order) as the problem that preceded it. This could also be interpreted as an indication that students respond to a given problem with an algorithm which first instructs them to apply, or attempt to apply, the solution strategy from the previous problem. Regrettably, no research has been performed to determine whether a significant number of errors on word problems are made when a student (mis)applies the operations he used in a previous problem, e.g., perhaps a student will be more likely to incorrectly multiply in an addition problem if it is presented in sequence after other multiplication problems. If such a situation exists, the solution is obviously to present sequences of problems in a mixed fashion (i.e., take the sequence variable into account) in an attempt to dissuade, rather than reinforce, the attainment of such algorithms.

The above arguments serve the purpose of depicting the confounding nature of the numbers in word problems. The major topic of interest here, however, is the correlation between computational skills and problem solving ability documented in the review section. While several researchers have found a positive correlation, the work of Jerman qualifies this. As mentioned previously, Jerman noted no significant differences between the treatment and control groups in terms of numbers of correct responses but did report highly significant differences in favor of the experimental group in choosing the correct procedures. This finding indicates that the process skills and the computational skills may be considered independent and therefore can be treated as such in the curriculum. Thus, the development of computational ability can be undertaken separately from the development of problem solving skills. This is exactly the intent of the Word Problem Program.

The separation of computation from process has been attempted in the past by researchers concerned with structural variables. In particular, Berglund-Gray and others at the University of Pittsburgh, performed their research under conditions in which the subjects were not required to perform arithmetic calculations. Instead the answer sheet consisted of a 4 X 2 matrix (for two step problems) with columns labeled "addition", "subtraction", etc. and rows numbered "1" and "2". To solve the problem, the student had to indicate the process by placing an "X" in the first row under the operation he would apply first and another "X" in the second row under the operation he would apply next. This method allowed the researchers to investigate problem solving without contending with the computational variable. The method did, however, have drawbacks. Since the subjects indicated only the operations they would use, the researchers had no assurance that the subjects were indicating the proper operands. Furthermore, although the researchers attempted to use only unambiguous problems, it was still possible to solve a given problem correctly using two different sequences of operations. The researchers, however, accepted only one of these.

More recently, Loftus used the computer to separate the computational and problem solving components. In the Loftus program, the subjects specified the operands and the operation to be used to solve a particular problem, and the machine did the computation. The manner in which the program format forced the subjects to reply (discussed elsewhere) was, however, unsatisfactory.

In the Word Problem Program, the computer will allow us to perform all calculations for the student without the negative aspects previously mentioned. A detailed description of the manner in which problems are presented and in which the student is expected to respond can be found in the section on Program Format.

NUMBER SENTENCES AND WORD PROBLEMS

Several researchers and educators presume a relationship between word problems and number sentences. This relationship is generally manifested in the role which number sentences play as a step towards the solution of word problems. In the Word Problem Program, we utilize number sentences in this fashion, but also hypothesize a different sort of relationship which involves the use of number sentences as a structural variable to aid in sequencing word problems. This section describes these and other uses of number sentences in the Word Problem Program.

I. Number Sentences as Instructional Strategy

Riedesel, on the basis of his review, urges teachers to

> make use of mathematical sentences in solving single and multi-step problems. This approach improves pupil ability to look for the salient aspects of problems and then select symbols that express this sense. Thus pupils can be taught to grasp the structure of the problem before "looking for the answer". However, care should be taken not to use the mathematical sentence as the only way to solve problems.

The Seeing Through Arithmetic (STA) program by Hartung et al., (1967), incorporates this strategy to the fullest extent. The STA program teaches two methods of problem solving. Students in the second and third grade are taught by the Action Sequence Method described in the review (Wilson based his method on the 1964 STA approach.) In this approach, students were to recognize the real or imagined action-sequence structure of a problem, express it as a number sentence, and solve the number sentence. However, students could only solve direct number sentences and thus, for some problems, they had to "imagine an appropriate second action sequence" and express it as a (direct) number sentence.

In the fourth grade, the STA approach changes and the student is directed to follow three steps of a general problem solving procedure:

(1) obtain from the verbal problem a mathematical sentence that describes the situation.
(2) process the sentence to get the unknown number in accordance with certain mathematical properties and definitions.
(3) Interpret the end result of the processing in terms of the original situation.

The method takes the student from the more concrete physical situation of the Action-Sequence method to the "mathematical world" of number sentences. The student is encouraged to find a direct or indirect number sentence to describe the problem situation. If the equation is indirect, he may solve it by applying what he has learned about the commutative property, the relationships between the operations, and about "related sentences." The method relies heavily upon the last concept. "Related sentences" are sentences which contain the same numbers and have the same solution, e.g. 3 X ? = 12, 12 = ? X 3, and ? = 12 / 3 are all related sentences. The student is expected to "know" the related sentences for any given sentence, and choose the one that tells him directly what operation to use. He then computes the solution and returns to the "physical world" to interpret it. The authors of STA state that this "general procedure can be used to solve all kinds of problems, no matter how difficult the problem may be."

The Wanted-Given programs of Wilson and Jerman also make use of number sentences. Wilson assumed that there exists an "essential" relationship between the "known and the unknown" or the "givens" and the "wanted" in word problems. The "wanted" number is seen as a particular kind of number: "a sum, a difference (or unknown addend), a product, or a quotient (or unknown factor)". In the Wanted-Given program the student is taught to recognize the wanted-given structure of the problem and to express it as an equation. In accordance with the program's definition of the arithmetic operations and the wanted-given structures, all of the number sentences should be direct and should not require further modification for solution. Wilson's program is only used, however, with one step word problems. Finally, Jerman's Modified Wanted-Given program also relies heavily upon number sentences. In Jerman's program, however, the students are encouraged to write indirect equations as partial solution to the word problems.

Each of the above instructional methods involves the use of number sentences to teach competency in solving arithmetic word problems. The methods differ in the manner in which the student is required to derive a number sentence from a given word problem. In the Word Problem program, the student is encouraged (though not required) to represent word problems as number sentences. This is accomplished through the HINT structure described in the preceeding section. The HINT structure suggests the strategy of first translating a given word problem into simpler terms (a modification of the analogy method) and subsequently translating the simplified problem into a (direct or indirect) number sentence. Thus, the principle differences between The Word Problem program and the aforementioned programs with regard to number sentences are:

(1) utilization of the proposed problem solving strategy is optional in the Word Problem program and mandatory in the other programs.

(2) The Word Problem program encourages a strategy of translation rather than one of recognizing hidden "structures" and "relationships" in word problems. We believe that this translation strategy will prove to be applicable to a wider range of problems than will the other strategies.

Since number sentences will play such an integral role in the Word Problem program, it is necessary to provide instruction in all aspects of their solution. For this reason, a number sentence program will also be developed which will parallel the Word Problem program. Thus, a student will be given a particular word problem only if he has already mastered objectives on number sentences identical to those attained from the word problem. Finally, the significance of number sentences to the Word Problem Program is manifest in both the method and the form in which the student is expected to respond to a given word problem. This will be discussed in the section on program format.

II. Number Sentences as a Structural Variable

In the review of the literature, several structural variables were described. Only the study by Rosenthal, however, dealt directly with the relationship of word problems to number sentences. Rosenthal studied three variables, one of which was concerned with number sentences. He generated word problems to correspond to number sentences of the form $M \pm N = ?$ and $? \pm N = P$. Rosenthal found that problems that correspond to the form $M \pm N = ?$ were significantly ($p < .001$) easier than those which correspond to the form $? \pm N = P$. This result indicates that there is indeed a strong relationship between word problems and number sentences. The purpose of this subsection is to relate the manner in which this relationship can be used to help answer some questions concerning word problems.

Many of the structural variables discussed in the review can be seen to be directly analogous to conditions present in number sentences. The most obvious of these are the steps, operations, and position of question variables. Other such variables, however, may be inferred. For example, the order variable (of numerical data) would be present if the numerical data in the number sentence did not correspond in order to that of the corresponding direct number sentence. In multi-operation number sentences, the order of operations variable may have a similar effect on number sentences as it did on word problems. Finally, one can even hypothesize a relationship between the structural complexity of a word problem and its corresponding number sentence.

On the basis of Rosenthal's findings and the above analogies, it seems reasonable to assume that number sentences, due to their simplicity, can aid in hierarchically ordering word problems. The question which now arises is how to utilize the relationship fruitfully. One obvious problem is that several different number sentences can be derived from a given word problem and, inversely, a multitude of word problems can be generated for any given number sentence. Two methods are under consideration to deal with such problems and enable us to utilize number sentences in ordering sets of word problems.

In the first method, we momentarily assume that we can translate a given word problem into a unique number sentence. After translating a set of word problems to their corresponding number sentences, we may either:

(i) utilize the resultant number sentence as a structural variable along with the sequential, conversion, length, and other syntactic variables to sequence the word problems using a Loftus-type regression equation, or

(ii) order the word problems purely on the basis of the number sentences, i.e., group the problems according to number sentence form and order as if they were number sentences; finer ordering (within groups) can then be performed on the basis of other structural variables.

Both of these alternative approaches to the first method require the generation of a number sentence from the given word problem. To be at all meaningful, the generated number sentence must be unique. This can be accomplished through the use of an algorithm which consistently generates the same number sentence for a given word problem. An example of an algorithm with this capability is the STUDENT program developed by Bobrow (1964). Bobrow's computer program can solve algebra word problems which have been written using a specific subset of the English language. The program accomplishes this by a series of translations of the text of the word problem into equations, and a subsequent solution of the equations. The existence of the STUDENT program confirms the plausibility of creating an algorithm which can translate a word problem into a unique number sentence.

The second method also involves an algorithm similar to the above, but makes use of the algorithm itself (as opposed to its product) to determine the difficulty of a problem. The algorithm would be more complex than that needed for the first method and thus, would probably be based more directly on Bobrow's work. The scheme for ordering the word problems is to generate an algorithm which solves problems by processes and operations analogous to and representative of those used by human subjects. An index could be generated on the basis of type and number of processes (or loops in the program) necessary to solve the problem. Sets of problems could then be ordered on the basis of individual indices.

The rationale behind the generation and utilization of such a complex algorithm is that it will produce results more directly representative of item difficulty than utilization of the structural variables discussed previously. The algorithm should give us a method for comparison of problems on the basis of variables more directly analogous to the actual skills and processes necessary for a student to solve the problems. The Bobrow program stands as evidence that an algorithm can be produced to solve word problems, and research is currently under consideration which will give an indication of the feasibility of applying such an algorithm to the task of ordering sets of problems. This research will be conducted using the analogous case of number sentences only, i.e., generating an algorithm to solve number sentences, ordering on the basis of an index computed by the algorithm, and checking the hypothesized ordering against empirical data.

The choice of which method to employ will be made primarily on the basis of time, feasibility, and resources. The order of preference for the alternatives is: method 2, method 1-i, and method 1-ii. Regrettably, this is also the order of difficulty. In the preliminary version of the Word Problem Program, a simplification of method 1-ii was used as a method of grouping sets of similar problems. This method was based on the direct number sentence and thus required no algorithm to generate unique number sentences for each word problem. Although this method seemed quite feasible and elaborations could be made with relative simplicity, it lacks the exactness and refinement of the more difficult and time consuming techniques.

III. Other Uses of Number Sentences

It has been indicated several times that the study of number sentences could aid in the study of word problems. An example of this is a recent, informal study of student protocols on objectives in one-step number sentences taken from the IPI Functions Program. Correct and incorrect responses were recorded and the incorrect responses were classified as resulting from errors in either computation or process. An error was classified as a process error only if the value attained by the student could be exactly calculated by application of the inverse operation on the two operands. Problems were also classified as belonging to one of six types (three when assuming symmetry about the equality relation):

Type 1: ? = a o b, a o b = ?
Type 2: a = ? o b, ? o b = a
Type 3: a = b o ?, b o ? = a

where "o" symbolizes one of the four operations. The results of a chi square test yielded significant differences between types ($X^2 = 57.48$, $p < .001$) and further analysis showed the following:

(1) Symmetry about the equality relation. Within each type, no significant difference was found between problems in which the operation appeared on the left or the right hand side of the equation. This finding allowed us to consider three rather than six types.

In an attempt to account for the differences between types, the total errors were classified as either due to process (8% of the total) or calculation (8% of the total).

(2) No significant differences were found between types of problems on the basis of errors in calculation

(3) significant differences were found between types ($X^2 = 54.32$, $p < .001$) on the basis of errors in choosing the correct process.

In light of these results, a further analysis of individual problems allows us to conclude that many of the students were operating under a peculiar and undesirable algorithm which relies heavily upon the operation symbol which appears in the problem and the particular nature of the numeric values in the problem. As an illustration of this, in the problem 6 / 3 = ?, the " / " cues the operation of division and the divisibility of the numbers supports this. However, the problems 6 / ? = 3 and ? / 3 = 6 are solved in the same fashion, the first correctly and the second incorrectly. In the second problem, where multiplication is required to produce the solution, the "/" and the divisibility of 6 by 3 cues the operation of division. Note, however, that whereas ? / 3 = 6 cues division, ? / 17 = 5 does not, and thus, due to the lack of divisibility, the correct(inverse) operation of multiplication will be chosen by default. By the application of such an algorithm, a surprisingly high percentage of problems can be answered correctly without the slightest understanding or application of the mathematical principles involved. An analogous situation exists in addition and subtraction problems.

The above situation can be seen to correspond to the phenomenon described by Stevenson and discussed in the preceeding section. This supports the suggestion that many children solve word problems by an undesirable algorithm, i.e., individual words or phrases cue operations, the validity of which can be checked on the basis of the divisibility or subtractibility of the numbers in the problem. If this is indeed the method employed by students to solve word problems, then efforts should be made to discourage its use. Two methods are under consideration to deal with this problem.

The first method prescribes that the student progress through the word problem and number sentence curricula in three levels:

(1) The first level allows only "legal" numbers as values in the problem. That is, no numbers of a magnitude or nature (e.g., decimals or fractions) to which the student has not been exposed will appear in the problem or in the solution. This is the "real" level in which the aforementioned undesirable algorithm works.

(2) The second level is designed specifically to mislead one who blindly applies an algorithm like that described above. For example, in the number sentence program, the numbers can be chosen randomly (to allow negative numbers and decimals as answers), or can be of greater magnitude than that to which the student has been exposed. Lack of familiarity with the numbers should not impede performance since all actual calculations will be performed by the machine. Also, numbers that are easily divisible will be used in problems requiring the student to multiply the numbers. The rationale for all of this is to eliminate the cues that the numbers themselves provide and, thus, to force the student to consider other reasons for choosing a particular operation. In the case of word problems, care must be taken to generate problems whose numbers do not cue operations and yet do not result in physically absurd problem situations.

(3) The third level will consist of problems in which only symbols appear. This purely abstract case is used to insure the understanding of the processes by the child.

The second alternative method constitutes a reversal of the first. The proposal is to teach the third level first, so that students begin by solving number sentence problems and, subsequently, word problems, with abstract symbols. The rationale here is to avoid the formulation of the algorithms mentioned. This would do away with the difficult task of leading the student to forget his old algorithm and relearn another. Furthermore, we believe that teaching the manipulation of abstract symbols first will develop skills which will transfer to the case of real numbers. This stands, however, in contradiction to the method of proceeding from the concrete to the abstract case and thus, the question of feasibility is paramount here. Clearly, this method should be neither accepted nor rejected without further study. A major portion of the proposed research on number sentences will be devoted to determining the feasibility of having elementary school students work with abstract symbols.

FORMAT OF THE WORD PROBLEM PROGRAM

As stated previously, the manner and form in which problems are presented and in which the user must respond will make an important contribution to the overall instructional effectiveness of the program. Several formats have been considered for use in the Word Problem Program and have been tried in an experimental context designed to simulate on-line computer conditions. One of these has been chosen for implementation. This section presents a discussion of the proposed format and a description of some alternative formats.

The proposed format was derived principally from that used in the Loftus study described in the review. It represents an attempt to refine the Loftus format into one which is far simpler and more appealing mathematically. The program proceeds as follows:

(1) A word problem is typed on the screen.

(2) The numeric data presented on the problem is listed beneath the problem (in order of appearance in the problem) and labeled with consecutive alphabetic characters, each on a separate line.

(3) The user must then respond with either "HINT" to get a hint, "DONE" to quit, "INSERT" to enter a new number for a conversion problem, the option described in (5), or, he may perform some arithmetic operation. To do this, he types the operands (represented by alphabetic symbols) separated by an operation symbol.

(4) The computer performs any calculations indicated by the user and displays the value labeled with the next available alphabetic character. The user is again given the options defined in (3).

(5) To indicate that his answer has been represented by an alphabetic character, the user types "ANSWER" followed by that character.

As an illustration, the following is an example of the interaction between the program and a student solving a one-step word problem. The student's responses follow the "***" and are underlined:

```
HOW MANY COINS DID BOB COLLECT
IF MARK HAS 10 COINS LESS THAN BOB
AND MARK COLLECTED 20 COINS?

                              GIVEN   A   10
                              GIVEN   B   20
*** B-A                         B-A   C   10
*** A+B                         A+B   D   30
*** ANSWER D
```

Two points of interest immediately arise: that of the format's practicality and its pedagogical value. With regard to practicality, preliminary studies indicate that students master the commands of the program in less than an hour, whereas the Loftus format required from 4 to 8 weeks (Loftus does not say how many hours) of practice problems to prepare the students for the word problem set. In terms of the pedagogical value, we hypothesize that many interesting and important mathematical skills and concepts can be shaped through the use of this format. We expect that utilization of the format will, by itself, accomplish many of the program's objectives in the realm of problem solving abilities. For example, to solve the above sample problem, the student must be able to associate the symbols "10" and "20" with the symbols "A" and "B". He must be able to represent the sum of the two numbers as "A+B" and associate the sum with the new symbol "D". Finally, he must specify his answer by its single symbolic representation. The significance of this last association should be clearer in light of the following discussion.

In one of the experimental tryouts of another format, a fifth grade subject was presented with a two-step multiplication word problem and asked to find a single number sentence to correspond to the problem. He was told that he could ask the experimenter to write anything he pleased to aid his memory and that he would have to state this request and his final solution.

The problem was:

IN ONE YEAR, BOB ENCOUNTERED 13 GROUPS OF MEN
AT EACH BALL GAME HE TRAVELED TO. IF THERE WERE
15 MEN IN EACH GROUP, AND BOB TRAVELED TO 5 BALL GAMES,
HOW MANY MEN DID HE SEE, TOTAL?

After a great deal of effort, the subject began to approach the solution:

S: ...X equals 13 times 5
000, so far so good
X equals 13 times 5
X equals 13 times 5, so, X times 15 equals how many he
saw in whole year, but I can't see how to put that into
a sentence. putting that in a sentence.
X times,
X equals 13 times 5 is,
X plus,
X times 13 equals X
E: X equals (?)
S: X equals 13 times 5, and X times 15 equals X
E: (writing) X times 15 equals X
S: a different X
E: a different "X"?
S: yeah
E: What do you want to call this "X"?
S: I'll call that X
(pause)
E: "Y"?
S: question mark
E: (writes "X x 15 = ?")

The subject was then reminded that he must express his answer as a single number sentence. After several attempts:

S: I wonder how you can make that in one sentence?
13 times 5 equals X,
thats my X right there, so
it must be

X times 15 equals question mark?
no, cause you don't know how you got the other X
to equal your question mark, so
X equals 13 times 5
13 times 5 equals X
X times 15 equals question mark. I just can't figure how
to do it.

The subject finally gave up his search for a solution. He had no difficulty later, however, in solving a two-step addition problem which he initially attacked from a different direction:

S: I'm gonna get into the same thing I got into the other one and
then I don't want to do that.
Um, 25 plus 35 plus 19 equals
Is that called one sentence?

His performance on this and other tasks indicate that his difficulty was not a lack of ability to generate two-step number sentences, but rather a lack of such fundamental processes as association and substitution. Other subjects working in this format and in the proposed format were found to exhibit similar behaviors. For example, in the proposed format, the same problem discussed above would be solved as follows:

```
                                  GIVEN   A   13
                                  GIVEN   B   15
                                  GIVEN   C    5
*** A X B                         A X B   D  195
*** D X C                         D X C   E  975
*** ANSWER E
```

Children initially had difficulty using this format to solve multi-step problems. On the basis of the trials with subjects, however, it is felt that training in responding to one-step problems in this format will enable the student to perform successfully on multi-step problems. That is, we expect that the process of associating and specifying the computed answer in terms of a single abstract symbol (in one-step problems) will transfer to the tasks of association and substitution in the aforementioned two-step problems. In addition to these skills, the primary purposes of utilizing this format are to develop a mathematical concept of variable and to develop skills in abstract symbol manipulation which will hopefully transfer to other areas of mathematics and, especially, to algebra.

As stated earlier, the above format has been chosen for implementation. Various other formats have been considered and are still being studied for possible use in either a complementary role or as a total replacement. The remainder of this section briefly examines some of these possibilities.

Several variations of the proposed format are worthy of consideration. One variation is to allow the student to type the numbers themselves, instead of typing their symbolic (alphabetic) representations, e.g., "5 + 2" instead of "A + B". Another is to allow inputs containing more than one operation at a time, e.g., to allow "A + B - C" (or "20 + 5 - 19") as an intermediate or final step. This variation, however, has undesirable aspects, such as the need for parenthesis to specify the order in which operations should be performed. These variations have been tentatively rejected due to the hypothesized superiority of the proposed format for accomplishing the problem solving objectives listed in the first section.

Another set of variations is based upon the experimental format described earlier in this section. In this format, the student is given a word problem and is asked to type a number sentence from which the solution to the word problem can be derived. The computer will then solve the number sentence and display the solution. If the number sentence typed by the student is indirect, the computer will display the corresponding direct number sentence before the solution. The student will then be asked if he thinks his solution is correct. If he responds negatively, he is asked to type a new number sentence. If he answers affirmatively, he is informed as to the correctness of his responses. This format is more directly related to the specific strategy whose use is promoted in the HINT structure. In effect, it assumes that a given word problem is considered solved when an appropriate number sentence is generated. Such a program must, of course, be closely integrated with the Number Sentence Program to assure the veracity of this assumption.

A modification of this format could allow students to solve a given word problem by writing more than one number sentence. The student could define variables in several sentences and combine these to form his answer. For example, a word problem with solution ? = A - B + C could be solved with the sentences X = A - B and ? = X + C. As is the case of the proposed format, each of these formats could be implemented with either numbers or with alphabetic symbols which correspond to numbers.

All of the above formats have been tentatively rejected on the basis of experimental tryouts for feasibility and the format's hypothesized relationship to the program goals. They are, however, still under consideration for use in some manner. For example, it may prove beneficial to program more than one format and utilize them at different stages within the curriculum. It is hoped that additional study will aid in the ultimate choice of program format.

EXPERIMENTAL VERSION OF THE WORD PROBLEM PROGRAM

In the winter of 1972, an experimental version of the Word Problem Program was created. In this version, the program generates and displays word problems on demand in the format described in section 5. The purpose of this section is to describe some technical aspects of the experimental version and to present some sample protocols of the program in operation.

The existing program types the specified word problem and allows the user to perform calculations, insert his own numbers, or ask for hints. The facilities to present hierarchical sequences of problems and to judge which level of problems to present next have not yet been programmed. The program is written in a high level interpretive language which is extremely well suited to program development, but unfit for use in the school environment because of its slow operating speed. The program is thus being rewritten in a high speed compiled language for school implementation.

The program generates word problems using a technique of item form generation. Certain words in the problem are left variable, i.e., at generation time, they may be chosen randomly from lists of appropriate words. For example, the NAMES list contains as elements the names: Lucy, Sue, Barbara, etc., and the BAG list contains: bag, pile, collection, container, etc. By using open grammatical sentence structures, many different problems can be generated from one item form. In the examples of item forms that follow, the variable elements of the form are written with the names of lists contained in parentheses. This notation means that a word is to be selected at random from the named list. When suffixes follow the name of the list, they refer to different elements: (NAME, 1) means to select one element from the NAME list, and (NAME, 2) means to select another element from the NAME list that is different from the first chosen. If the same number appears twice in the item form, it refers to the same element already chosen, and not to a new random element. Two part lists also exist in which the first and second parts of the list are related in some fashion, e.g., singular and plural of the same word. Thus, (GROUPS, P1) refers to a randomly chosen element of the first part of the GROUPS list, and (GROUPS, P2) refers to the corresponding second element. (PRONOUN, 1, NOM) refers to the nominative form of the pronoun for (NAME, 1). Thus, the symbolic form (NAME) (OBTAIN, P2) (A) (OBJECTS) could be translated as JOHN HAD 18 BALLS or as MARY FOUND 4 APPLES. The following are examples of item forms from two of the existing 14 classes:

(1) Class MM (Multi-Multiplication)
EACH OF (A) (GROUPS, P2) (GAVE) (NAME) (B) (BAGS)
OF (OBJECTS). HOW MANY (OBJECTS) DID (NAME)
RECEIVE IF EACH OF THE (BAGS) CONTAINED (C)(OBJECTS)?

(2) Class A/M (Addition/Multiplication)
(NAME, 1) (OBTAIN, P2) (A) (OBJECTS). IF (NAME, 2)
(OBTAIN, P2) (B) TIMES AS MANY (OBJECTS) AS (NAME, 1),
HOW MANY (OBJECTS) DID THEY (OBTAIN, P1) (ADDWORD)?

At present, approximately 125 item forms have been programmed, each with the capability of generating thousands of unique word problems. These item forms are divided into 14 classes on the basis of the operations and number of steps necessary for solution. In the following sample protocol, the first problem has been generated from item form (1) above and the next two were both generated from item for (2). As before, the students responses are underlined.

```
EACH OF 7 MEN SOLD BETTY 12 BOXES
OF CANDY BARS.  HOW MANY CANDY BARS DID BETTY
RECEIVE IF EACH OF THE BOXES CONTAINED 10 CANDY BARS?
                         GIVEN  A  7
                         GIVEN  B  12
                         GIVEN  C  10
*** AXB                  A X B  D  84
*** DXC                  D X C  E  840
*** ANSWER E           ANSWER E    GREAT!
ANOTHER?
*** YES
```

```
BILL FOUND 23 STAMPS.  IF JANE
FOUND 6 TIMES AS MANY STAMPS AS BILL,
HOW MANY STAMPS DID THEY FIND TOGETHER?
                         GIVEN  A  23
                         GIVEN  B  6
*** HINT
HINT:  THE PROBLEM ASKS YOU TO FIND THE NUMBER OF
STAMPS THAT BILL AND JANE HAVE, TOGETHER.
*** AXB                  A + B  C  29
*** ANSWER C          ANSWER C     WRONG ANSWER
*** HINT
HINT: THE PROBLEM IS SIMILAR TO THE FOLLOWING ONE:
IF JANE HAS 6 TIMES BILL'S 23 STAMPS,
THEN BILL'S STAMPS PLUS JANE'S STAMPS = ?
*** AXB                  A X B  D  138
*** A + D                A + D  E  161
*** ANS E             ANSWER E     GREAT!
ANOTHER?
*** YES

JUDY BOUGHT 9 PEARS. IF SALLY
BOUGHT 15 TIMES AS MANY PEARS AS JUDY,
HOW MANY PEARS DID THEY BUY IN ALL?
                         GIVEN  A  9
                         GIVEN  B  15
*** INSERT 135          INSERT  C  135
*** A + C                A + C  D  144
*** ANS D             ANSWER D     GREAT!
ANOTHER?
*** NO
GOODBYE NOW
```

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Sister Claire McCormick's curriculum project, developed for this course and the introduction and Conclusion of her Analysis of the NRS Reading Program completed during her internship. The detailed level-by-level analysis is lengthy and is omitted from this report.

A

CURRICULUM PROJECT

PROGRAM 2

S. Claire McCormick
July 24, 1972

INTRODUCTION

This is a project undertaken as preparation for an internship in the Reading Program at LRDC. There are many paths of approach to a designated terminal point. The terminal point, in this case, is entry into a curriculum writing or curriculum development project. There are many ways of going about an instructional task, of facilitating the progress of the student from where he is to where he wants to be. The strategy chosen here is that of modeling.

The model in this instance is a small segment of the materials of level 3 of the New Reading System. From level 3 have been selected four representative sequences written as cassette-scripts: 3-1-A, 3-1-B, 3-1-R, and 3-4-A. The observation of the model becomes a scrutiny which seeks to extract from the materials the programming techniques evidenced therein.

The analysis of the materials, then, speaks to the problem:

> To what extent can scientific principles as developed in behavioral psychology and applied in programmed instruction be utilized in designing primary grades reading materials for individualized instruction?

It is intended that the resulting analysis provide an introduction to work in the total project. This should enable the student to enter with a better preparation for the work of the project because the activities here exemplified have provided the needed familiarization.

****

The content here presented includes three sequences on the digraph ch and one sequence on the word families derived from ot, et, and it. The component skills in clude: response differentiation, association, multiple discrimination, chaining, and concept formation.

The concepts include these generalizations:

--- Printed letters (symbols) represent spoken sounds and mean the same thing as the sounds.
--- Printed words are composed of sounds and sounds are represented by printed symbols.
--- There are root words which can have endings attached.
--- There are word families which differ only in their initial phonemes.

Since the program has been very carefully developed, it can simply be stated that the prerequisites for entry into the sequences under study is successful completion of the prior sequences. For entry into the program there are no requirements specifically related to reading. The child who is ready for first grade in an American city school should be ready for this program.

****

What follows are four separate analyses of the four cassette-scripts mentioned above.

ANALYSIS OF LEVEL 3 NRS

CASSETTE 3-[illegible]-A
PAGES 133,134,135

Claire McCormick
7/24/72

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CASSETTE SCRIPT 3-[illegible]-A
RESPONSE PAGES 133, 134, 135

CONTENT

WORD FAMILIES BUILT FROM: OT, ET, IT

— — — — — — — — — —

PAGE 133 : PRESENTS THE OT FAMILY

PAGE 134 : PRESENTS THE ET FAMILY

PAGE 135 : PRESENTS THE IT FAMILY

— — — — — — — — — —

OBJECTIVES

(DERIVED FROM THE MATERIALS)

1. THE STUDENT WILL ASSOCIATE TWO LETTERS (OT, ET, IT) WITH SINGLE SOUND.

2. THE STUDENT WILL GENERALIZE OR CATEGORIZE WORDS ACCORDING TO SOUND FAMILIES.

3. THE STUDENT WILL IDENTIFY THE SIMILAR ELEMENT IN SETS OF WORD FAMILIES.

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[illegible] [illegible] 3-[illegible]
[illegible] [illegible] 133, [illegible]

Excellent analysis

SKILLS (GAGNÉ)

1. RESPONSE DIFFERENTIATION
   · STUDENT MUST BE ABLE TO DISCRIMINATE THE INITIAL SOUNDS AND SYMBOLS IN EACH OF THE WORD FAMILIES.

2. ASSOCIATION
   · THE STUDENT MUST BE ABLE TO RELATE THE SOUNDS /OT/, /ET/, AND /IT/ TO THE LETTER OT, ET, AND IT AS THESE APPEAR IN WORDS.

3. MULTIPLE DISCRIMINATION
   · STUDENT MUST RESPOND TO DIFFERENT WORDS CONTAINING THE SAME ELEMENT (OT, ET, IT).

4. CHAINS
   · STUDENT MUST BE ABLE TO RESPOND TO LISTS OF FAMILY WORDS AND TO FAMILY WORDS USED IN JINGLES.

5. CONCEPTS
   · STUDENT MUST BE ABLE TO DISCRIMINATE DIFFERENT WORDS AND DIFFERENT WORD FAMILIES.
   · STUDENT MUST GENERALIZE OR CLASSIFY WORDS ACCORDING TO FAMILIES.

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3—4—A

1. ot

2. cot

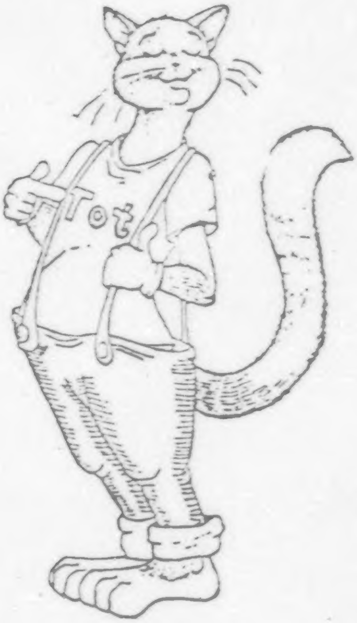
not

pot

lot

Tot

3.



PROGRAMMING TECHNIQUES - PAGE 133

STIMULUS

VERBAL (AURAL AND VISUAL) - WORD FAMILY SOUND AND WORDS OF THE FAMILY

SYMBOLIC - CHART-LIKE ARRANGEMENT

PICTORIAL - ANIMATED, IMAGINARY REPRESENTATION OF A CAT

RESPONSE

SELECTIVE - POINTING TO THE WORDS AND PICTURES

VOCAL - ECHOING AND PRODUCING INDEPENDENTLY

MOTOR - POINTING

AFFECTIVE (POSSIBLY) - TOT LIKES HIS NAME

PROMPTS

FORMAL - RHYMING; FRAME STRUCTURE (CHARTS)

THEMATIC - CAT, A FAMILIAR ANIMAL

MANAGEMENT - ATTAINMENT: READING A LIST OF WORDS

REINFORCEMENT: IMMEDIATE CONFIRMATION

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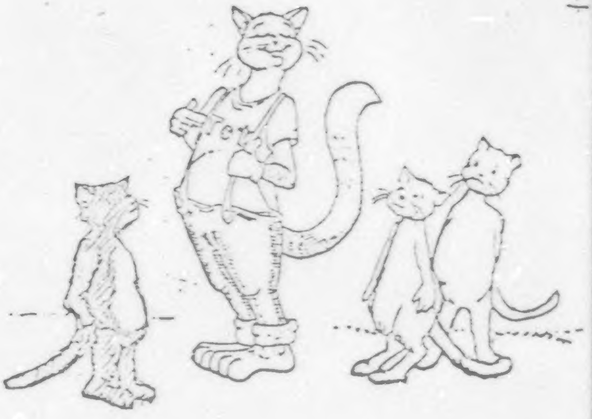
4.

The cat nām~~e~~d Tot

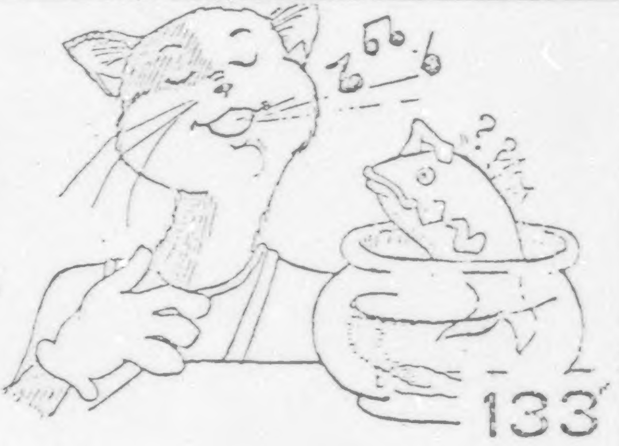
is the best of the lot.



5.

"I can sing," said Tot,

"and a fish can not."



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PROGRAMMING TECHNIQUES - PAGE 133

STIMULUS

PICTORIAL - ANIMATED ANIMAL FIGURES
VERBAL - WORDS IN SENTENCES
SYMBOLIC - UNDERLINING OF FAMILY WORDS

RESPONSE

SELECTIVE - POINTING TO CORRECT WORDS; FINDING THE FISH
CONSTRUCTED - SUPPLYING THE MISSING WORDS FOR THE VOICE ON THE TAPE
VOCAL - REPEATING ORALLY THE CORRECT WORDS
MOTOR - POINTING AND MARKING WITH X.

PROMPTS

FORMAL - RHYMES
THEMATIC - PICTURES TO MEDIATE MEANING

MANAGEMENT

MOTIVATION - ATTRACTIVE PICTURES; ACTIVE PARTICIPATION
REINFORCEMENT - IMMEDIATE CONFIRMATION

BEST COPY AVAILABLE

[illegible] [illegible] [illegible] 135 - PAGE 134

FRAMES 1,2, AND 3

EXCEPT FOR THE [illegible] II, THE WORDS AND THE ILLUSTRATION, THESE FRAMES ARE EXACTLY LIKE FRAMES 1,2,& 3 ON PAGE 133.

THE TAPE SCRIPT HAS SOME VARIATION BUT THE DIRECTIONS ARE ESSENTIALLY THE SAME.

ONE IMPROVEMENT MIGHT BE TO GIVE THE MORE DETAILED DIRECTIONS FOR CIRCLING IN THE FIRST SET RATHER THAN THE SECOND.

FRAMES 4,5,6

THESE FRAMES PRESENT ESSENTIALLY THE SAME TYPES OF STIMULI AND CALL FOR THE SAME TYPES OF RESPONSE.

PAGE 135 - FRAMES 1-5

THESE FRAMES ALSO UTILIZE A FAMILIAR FORMAT AND SIMILAR DIRECTIONS TO THOSE OF THE PREVIOUS TWO PAGES.

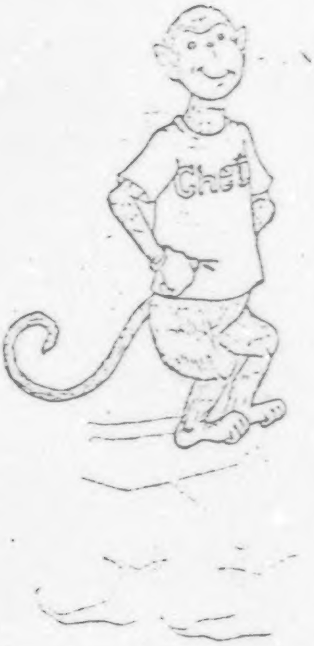
A NEW FEATURE IN THIS SET IS THE LONG MARK OVER A IN NAMED AND THE SLASH FOR THE SILENT OR ELIDED E.

et

2.

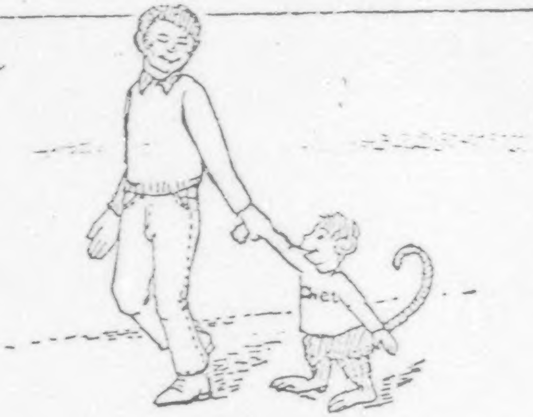
met
set
let
net
pet
Chet

3.



4.

This is Chet.
Chet is a pet.



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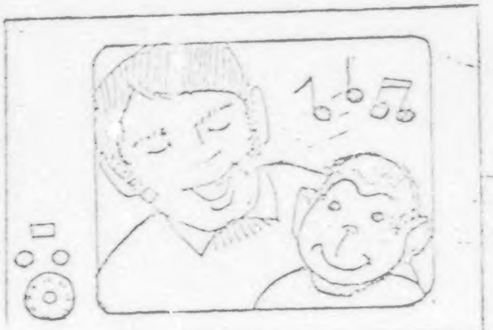
5. The man is on the T.V. set.
The man is singing to his pet.



1.

it

2.

sit

bit

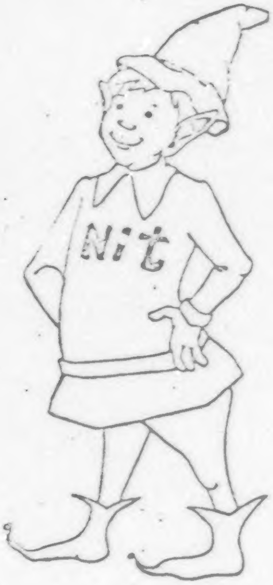
fit

pit

lit

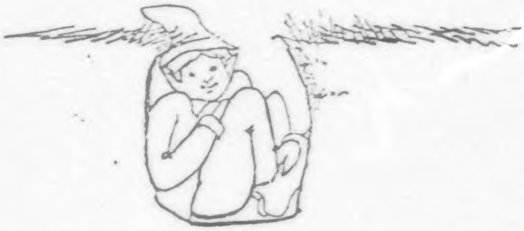
Nit

3.



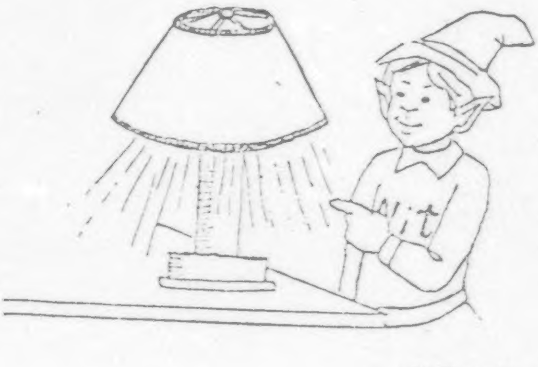
4.

The elf nāmed Nit
is sitting in a pit.



5.

"That's the lamp I lit."
Said the little elf Nit.



Cassette Script 3-4-A
Response Pages 133, 134, and 135

Let's check to see that you are on the right page. You should see 3-4-A in the box at the top of your page. (2 SECOND PAUSE) If you see 3-4-A in the box, you are on the right page and we can begin. (1 SECOND PAUSE)

Find the box next to numeral 1. (1 SECOND PAUSE) Point to the letters in box 1 as I say the sound these letters make together. Ready: /ot/. Now, you say the sound the letters make. (2 SECOND PAUSE) The letters o-t make the sound /ot/. Point to the letters and say their sound outloud with me. Ready: /ot/.

Next to numeral 2 there is a box with five words in it. Do you see the box? ($\frac{1}{2}$ SECOND PAUSE) I'll read the words in the box, you point to each word as I read. Ready by the first word: cot, not, pot, lot, tot. Do you see what is the same about all those words? (1 SECOND PAUSE) All those words end the same. They all end with the letters o-t. The letters o-t make the sound /ot/. I'll read the words in box 2 again, but this time I want you to read each word outloud with me. Ready: cot, not, pot, lot, tot. Now, I want you to read each word in box 2 yourself, then draw a ring around the letters o-t, the letters that make the sound /ot/. (STOP)

Look at the picture of the cat beside numeral 3. (1 SECOND PAUSE) Tot is the name of the cat pictured next to numeral 3. Look at Tot. (1 SECOND PAUSE) Tot likes his name so much he has it printed on his shirt. Read the name on the cat's shirt with me. Ready: Tot. Tot not only likes his name, he likes all /ot/ words. Tot's favorite words are all of the /ot/ words in box 2.

Go to numeral 4. (1 SECOND PAUSE) There's a two line rhyme next to numeral 4. Point to each word as I read the rhyme. Ready by the first word: The cat named Tot -- is the best of the lot. You can see from the picture that Tot does think he's the best. I'll read the rhyme next to numeral 4 again, but when we come to an underlined word, you read that word outloud. Ready: The cat named (2 SECOND PAUSE) is the best of the (2 SECOND PAUSE). Did you read Tot and lot outloud?

Go to numeral 5. (1 SECOND PAUSE) Next to numeral 5 is another two line rhyme. Follow along by pointing to each word as I read the rhyme. Ready: "I can sing," said Tot, "and a fish can not." The picture shows a fish watching Tot sing. Make an X on the picture of the fish. (2 SECOND PAUSE) I'll read the rhyme next to numeral 5 again, but when we come to an underlined word you be sure to read that word outloud. Ready: "I can sing," said (2 SECOND PAUSE), "and a fish can (3 SECOND PAUSE)." I hope you read Tot and not outloud.

Turn to the next page. (5 SECOND PAUSE) You should be on page one hundred thirty-four. (2 SECOND PAUSE) If you are on page one hundred thirty-four, you are on the right page and we can continue the lesson. (1 SECOND PAUSE)

Find numeral 1 at the top of your paper. (1 SECOND PAUSE) Point to the letters in the box next to numeral 1 as I say the sound these letters make. Ready: /et/. Now, you say the sound. (2 SECOND PAUSE) The letters e-t make the sound /et/. You say /et/ with me again. Ready: /et/.

Go to box 2. (½ SECOND PAUSE) All of the words in box 2 end with the letters e-t. The letters that say /et/. I'll read all of the /et/ words in box 2. You follow along by pointing to each word as I read. Ready by the top word: met, set, let, net, pet, Chet. This time, I want you to read each word in box 2 outloud with me. After we read a word, I will give you time to draw a ring around the letters e-t, the letters that say /et/ in each word. Ready by the top word in box 2: met. Now, draw a ring around the two letters that make the /et/ sound in met. (3 SECOND PAUSE) Go to the next word. Ready to read: set. Ring the letters that make the /et/ sound in set. (3 SECOND PAUSE) . . . next word. Ready: let . . . ring the letters that make the /et/ sound in let.. (3 SECOND PAUSE) . . . next word . . . net . . . ring the letters that say /et/. (3 SECOND PAUSE) . . . next word . . . pet . . . ring the letters that say /et/ in pet. (3 SECOND PAUSE) . . . last word . . . Chet . . . ring the letters that say /et/ in Chet. (3 SECOND PAUSE)

Look at the picture of the monkey next to numeral 3. (1 SECOND PAUSE) Chet is the name of the monkey pictured next to numeral 3. Chet likes his name so much he wears it on his shirt. Do you see Chet's name on his shirt? (1 SECOND PAUSE)

Next to numeral 4 is a rhyme that tells us about Chet. (1 SECOND PAUSE) Follow along as I read the rhyme next to numeral 4. Ready: This is Chet. Chet is a pet. Look at the picture. (1 SECOND PAUSE) The picture shows Chet walking down the street with a man. Chet is the man's pet. I'll read the rhyme next to numeral ~~3~~ 4 again, when we come to an underlined word, you read that word outloud. Ready by numeral ~~3~~ 4: This is (2 SECOND PAUSE). Chet is a (2 SECOND PAUSE).

Go to numeral 5. (1 SECOND PAUSE) Follow along as I read. Ready: The man is on the T.V. set. The man is singing to his pet. The picture shows the man singing to his pet. Make an X on Chet the pet. (3 SECOND PAUSE)

Turn to the next page. (5 SECOND PAUSE) Check to see that you are on page one hundred thirty-five. (2 SECOND PAUSE) We can continue the lesson if you are on page one hundred thirty-five. (1 SECOND PAUSE)

Find numeral 1 at the top of your page. (1 SECOND PAUSE) I'll say the sound the letters in box 1 make. Listen: /it/. Now, you say the sound these letters make. (2 SECOND PAUSE) The letters i-t make the sound /it/. Say the sound with me again. Ready: /it/.

Go to box 2. (1 SECOND PAUSE) I'll read the words in box 2, you follow along by pointing to each word as I read. Ready by the top word: sit, bit, fit, pit, lit, Nit. All those words end the same, they end with the /it/ sound. The /it/ sound is made by the letters i-t. You make a ring around the letters in each word in box 2 that make the /it/ sound. (STOP) Let's read the words in box 2 outloud together. Ready by the first word: sit, bit, fit, pit, lit, Nit. Now, read the last word in this box outloud by yourself. (2 SECOND PAUSE) Nit is the last word. Nit is the name of the elf pictured next to numeral 3. Look at Nit. (1 SECOND PAUSE) Nit wears his name on his shirt. Do you see Nit's name on his shirt? (1 SECOND PAUSE)

Go to numeral 4. (1 SECOND PAUSE) Follow along by pointing to each word as I read the rhyme next to numeral 4. Ready: The elf named Nit -- is sitting in a pit. The picture shows Nit sitting in a pit. (½ SECOND PAUSE) Do you see Nit sitting in a pit? (½ SECOND PAUSE) I'll read the rhyme next to numeral 4 again. When we come to an underlined word, you read that word outloud. Ready: The elf named (2 SECOND PAUSE) is sitting in a (2 SECOND PAUSE). If you read the words Nit and pit, you were exactly right.

Go to numeral 5. (1 SECOND PAUSE) I'll read the first sentence, then you read the second sentence yourself. Ready: "That's the lamp I lit." Now, you read the second sentence outloud by yourself. (STOP) Did you read the second sentence outloud? This time, read both sentences outloud with me. Ready: "That's the lamp I lit." Said the little elf Nit. The picture shows Nit pointing to the lamp he lit. You make an X on the lamp that Nit lit. (3 SECOND PAUSE)

That's all for this lesson. Goodbye.

CONCLUSION

In this project I have attempted to extract simply by observation of the materials, the objectives, skills, and techniques in four separate cassette-TAPE SEQUENCES. The model employed for this analysis is a variation of the presentation model of Tosti and Ball as delineated in their article, "A Behavioral Approach to Instructional Design and Media Selection", AV Communication Review, Vol. 17, no. 1, Spring 1969.

The most important part of frame is the response it evokes. Within the small scope of these four sequences the types of response called for have been many and varied. An inspection of the analysis will show this.

The final test of curriculum materials is in the empirical tryout. Likewise, in a systematic approach to curriculum development no segment can be judged accurately apart from its relationship to other elements (teacher input, games, puzzles, and books). However, within the confines of these particular materials there seems to be a systematic approach derived from science coupled with a variety and appeal to children which indicates the artistry of the designeer.

These materials look very good to me, and I am looking forward to working in the program.

AN ANALYSIS OF SELECTED SEGMENTS OF NRS

S. Claire McCormick
November 30, 1972

"Not until the middle of the next week, however, did a nontrivial idea emerge. ... Suddenly I realized the potentially profound implications of a DNA structure in which the adenine residue formed hydrogen bonds similar to those found in crystals of pure adenine."

James D. Watson in
The Double Helix

The challenge of this new age is to create.

Rollo May
November 15, 1972

We must learn to see everyday things in new ways.

Ladislaus Orsy
November 18, 1972.

N.B. THIS DOCUMENT CONTAINS
SIX SECTIONS

SECTION I

Introduction

This project was undertaken during the third semester of a three-semester training program in curriculum development. The training program presented the students---potential curriculum developers---with a systems model for curriculum development. The model had general applications to almost any area of learning and instruction. The purpose of the first year of the training program was to enable the students to build a knowledge base for the production of instructional materials in a subject matter field or discipline of their choice.

The purpose of the project presented here was to provide the student with some prefamiliarization for work during a second year as an intern in the Reading Project at the Learning Research and Development Center of the University of Pittsburgh.

My choice of reading as an area of concentration stems from three factors: 1) my plans for future involvement in the problems of urban education in the United States; 2) my perception of the acquisition of reading skills as one of the central problems of urban schooling; and 3) my past experience as an elementary school teacher and later as a teacher of Latin in secondary school. All of these factors provide motivation as well as some of the required skills.

The Problem

The term problem is used here in a more general sense than it occurs in the literature of experimental design or in works devoted to the development of theory. This project addresses itself to what might be considered a goal of research in education: the application of scientific theory to the development of educational materials. This project is neither an experiment nor an explication of theory. It is an analysis of educational materials which were produced in accordance with theoretical principles. If educational design is considered as an experiment, then this project looks at the completed experiment and analyzes it for the elements assumed by the theory from which the experiment originated.

The structure of the New Reading System (NRS) was presented to the staff of the Learning Research and Development Center by Mrs. Isabel Beck, its designer, in the spring of 1972. It appears in written form in the document "The Rationale and Design of a Primary Grades Reading System for an Individualized Classroom" by Isabel L. Beck and Donna D. Mitroff. These two presentations represented a synthesis of theoretical knowledge of the reading process into goals and guidelines for actual practice.

In order to address the more general problem of theoretical applications to the design of educational materials, I chose a rather specific task. This task can be described as follows:

> to analyze selected sets of response sheets with accompanying tape scripts from level 3 of NRS for the programming techniques utilized therein.

Since this was to be an in-depth study, only four sets of response sheets with their accompanying scripts were selected. I hoped to come to understand and to appreciate the design for NRS which already existed. I needed to infer the theory which guided the development of these specific samples of the materials, and to understand, as far as possible within the limitations of time and expertise, how and why these materials worked. Implicit in the task of this project was the concomitant task of constructing a scheme for carrying out the analysis.

Description of NRS

The New Reading System is just what its name implies, a system for learning and instruction in reading. It differs from the traditional reading programs in that it develops in a related and inter-dependent manner a large and capable-of-being-added-to number of components. According to Chall's study (Chall, 1967), which was completed during the years 1962 to 1965, the "complete programs" included nothing more than textbooks and exercise materials for the pupils and guidebooks for the teacher. While "supplementary" materials of many types may be used with these so-called "complete" programs, there is no over-all integrating design. The integration, if any, must depend upon the ingenuity and time availability of the teacher to plan and to implement. The New Reading System comes to the teacher as the artifact of a carefully structured systems design.

These systems or environmental characteristics of NRS can be both everwhelming and elusive to the uninitiated. The observer hardly knows where to begin in order to really "see" what is there. Viewing the system entails looking at it "in its entirety with all of its ramifications, with all of its interior interactions, with all of its connections, and with full cognizance of its place in its context." (Mood in Richmond, 1970)[1] As an aid to understanding the structure of NRS and to placing the analysis within the structure of NRS, a chart highlighting the essential features of NRS is presented in figure #1.

In the first two levels, those preceding the segments to be analyzed in this paper, the most important strategy is the algorithm for the blending chain. "The strongest advantage of the blending chain is the precise information available to the teacher in terms of locating an error."[2] The entire code-breaking approach makes the generative principles of the language directly available to the child.[3] Thus the child is given an early tool for word attack.

NEW READING SYSTEM

DOMAIN - TRADITIONAL FIRST THREE YEARS OF READING INSTRUCTION

POPULATION - CITY CHILDREN IN U.S.A.

SPECIAL FEATURE - INDIVIDUALIZED IN:
RATE - PRESCRIPTION
ROUTES - SELECTION
PUPIL CHOICE AND ALTERNATE PATHS

STRUCTURE - 16 LEVELS:
10 SEQUENCES PER LEVEL

FUNCTION - TO TEACH NEW SKILLS
TO MAINTAIN OLD SKILLS
TO BUILD FLUENCY
TO PERMIT "DISCOVERY" LEARNING

SCOPE - READING IN ITS BROADEST SENSE:

"the perception and comprehension of written messages in a manner paralleling that of the corresponding spoken messages."
(CARROLL, 1964)

APPROACH - CODE-BREAKING:
SYNTHETIC PHONICS
ANALYTIC PHONICS
LINGUISTIC PATTERNS
CONTEXTUAL PRESENTATION OF:
LETTER/SOUNDS; WORDS/MEANINGS

NRS is an individualized-adaptive system, a student-centered environment.

THE RATIONALE AND DESIGN OF A PRIMARY GRADES READING SYSTEM, BECK AND MITROFF, 1972.

FIGURE 1.

"Once the child enters Level III, the cassette becomes the primary vehicle for the presentation of new material."[4] This means that during the preceding two levels self-management skills have had to be developed. It also means that at the beginning of Level III the teacher assumes a new role, that of "traveling teacher". The teacher's task now is to guide, motivate, reinforce and tutor.

The strategies and conventions which formed an important aspect of the teacher's role during Levels I and II are now subsumed into the cassette-led instruction. The major learning interaction shifts from the teacher present in the classroom to the master teacher made present through the design of the materials, the tape and response sheets. Thus a continuous communication and control can replace the intermittant and less structured guidance of the traditional reading classroom. What happens at Level III is the implementation of a man-machine system; i.e., a learner, a program, and a teaching machine (the cassette tape recorder).

At this point system conventions assume a strategic importance. "System conventions are the arrangements of frames, the directions to children, and the types of responses children must make."[5] It is here that both the scientific soundness and the artistic inventiveness of the designer in implementing the prescribed design decisions are evidenced. It is here that the power of the program is critical. The critical nature of these conventions is examined in this analysis.

Theoretical Base

This project, then, is a study of the application of the science of technology to the design and development of curriculum materials. Educational technology has been defined as "the application of scientific knowledge about learning, and the conditions of learning, to improve the effectiveness and efficiency of teaching and training."[6] Scientific knowledge about learning has been derived from laboratory experiments of psychologists and finds expression in various learning theories. This project is concerned with the contributions of theories of learning to the design of instruction.

Bruner[7] has contrasted the nature of learning theories with that of instructional theories. He identifies a theory of learning as descriptive and a theory of instruction as prescriptive. Learning theories fall into two main categories: 1) those concerned with controlling the stimulus or creating the environment for learning, the behavioral theories; and 2) those concerned with the internal processes, the cognitive theories. Theories of instruction derive from theories of learning and are, because of the primitive stage of the development of both types of theory, probably best described as eclectic.

A theory of instruction is a normative theory in that it sets forth rules[8] concerning or specifying the most effective way of achieving knowledge or mastering skills. A theory of instruction establishes a criterion and then states the conditions for meeting it. Theories of instruction have practical application wherever the teaching-learning process is in effect.

A scientific approach to education produces procedures with predictable effects. It provides the kind of control of the learning events which comes from planning and deliberate design. One form of planning is the specification of goals and objectives. Objectives identified as terminal for a course or program can be still further analyzed. Greater specificity and detail provide the guidance needed to construct or to choose particular instructional items. This type of objective forms a guide to the creation of very fine-grain increases in pupil competence.[9]

The programmed instruction movement has this strong behavioral orientation. Its development is traced through Pavlov's classical conditioning to B. F. Skinner's operant conditioning as well as through the development of the first teaching machine by Sidney Pressey in the 1920's. Instructional programs for use in schools, however, are a phenomenon of only the last decade or so.[10] Adaptations of more formal pencil and paper programs as well as the development of the concept of an instructional system is as yet a new and rare phenomenon for the professional educator. Today programmed learning is only gradually coming to be viewed as a process rather than a product.[10] The products should developed to facilitate the total process.

The purpose of programming is to maximize the rate of learning, the length of retention as well as to enhance the motivation of the student.[11] Teaching implies first and foremost a human interaction.[12] On the part of the teacher this interaction involves a controlling role, a facilitating role and a content development role. In addition, the teacher performs roles which can be identified as personally responsive and positively or negatively affective. A carefully developed program should subsume the first three functions of a good teacher.

For optimum efficiency of a program, continuous interaction is necessary. By designing the instruction through a master teacher it is possible to take the planned instruction of a single teacher and implement it for a large number of students. This makes possible the best available conditions for learning and instruction. This type of modification results in a man-machine system. Once such a system has been conceptualized, what is necessary is to optimize the man-machine functions.

There are three critical system functions: 1) the cue function; i.e., the stimulus to which each criterion response is attached; 2) the motivation function, eliciting the desired performance; and, 3) the feedback function, providing immediate knowledge of results.[13] An important characteristic of successful instructional theory is that it is conceived with particular reference to the role of student response.[14] In applying these principles to a particular segment of curriculum materials, an educator needs some facility in determining the type of response which the materials have been designed to elicit.

When an individual responds in a certain way to a given stimulus, that stimulus is said to control behavior. A primary objective of educational technology is the guidance of an individual's responses. To accomplish this, the instructor must first define and enumerate the responses he wishes to produce. He must arragne stimulus conditions which will result in the desired response, and he must decide the response consequences. Teaching requires the establishment of successively more rigorous standards for the learner's responses.[15] Thus the sequencing of stimuli becomes another important task for the designer.[15]

Once the criteria or objectives of a sequence have been set, the construction and sequencing of frames can begin. The elements of a teaching frame are: stimulus, prompt, response and reinforcement. Each of these elements can be studied in detail and in relationship to one another. However, it should be kept in mind that the most important part of the frame is the response it evokes. Frame construction is a matter of behavioral guidance and not ~~only~~ merely a matter of subject matter exposition. The purpose of a frame is to let a response occur.

The basic principles of programming can be summarized in these five statements:

1) Perform a behavioral analysis.
2) Provide for continuous active responding.
3) Provide for immediate confirmation of response.
4) Allow for self-pacing and small steps (a relative term).
5) Perform a validation of the above steps.

Possibly the most effective reinforcer in a programmed sequence is successfully doing things which could not previously be done.[16]

Since the response is crucial and behavioral theory from which programming techniques have evolved simply surrounds the response with the relevant observable elements, it is necessary and profitable to resort to other theorists for a closer study of the response itself. Gagné has probably done more than any other cognitive psychologist to analyze the types of responses produced in a learning situation. As an instructional psychologist, Gagné has produced a scheme for the analysis of cognitive skills which relates behavior as closely as possible, within the limits of present knowledge, to the cognitive processes required to produce the desired behavior.[17]

Also related to the concept of behavioral analysis is the idea of "learning hierarchy". Gagné used the term as early as 1962 to refer to "a set of specified intellectual capabilities having, according to theoretical considerations, an ordered relationship to each other."[18] This aspect of instructional theory requires the learning technologist to examine in a very detailed manner the type of cognitive activity which a response to a specific frame or set of frames (segment of instructional materials) elicits. The value of a learning hierarchy to the instructional designer has also been well-stated by Gagné himself. "What it (a learning hierarchy) represents is the most probable expectation of greatest positive transfer for an entire sample of learners concerning whom we know nothing more than what specifically relevant skills they start with."[19] Since transfer is the ultimate test of successful learning, any scheme which enables the designer to anticipate transfer is certainly a powerful technique.

The analysis carried out here had three parts: 1) the behavioral objective for the segment was induced from the materials; 2) the cognitive skills in accordance with the scheme of Gagne were also induced from the materials; and, 3) a detailed analysis of the elements of each frame was made in accordance with the model displayed in figure 2.

What follows is a four-part application of the analysis described above. Since the model developed as the project progressed, the first segment's analysis is somewhat different from that of the next three. A discussion and conclusions follow the detailed analysis.

MODEL FOR ANALYSIS OF INDIVIDUAL SEQUENCES OF PROGRAMMED INSTRUCTIONAL MATERIALS *

RE: FRAMES

STIMULUS	PROMPTS	RESPONSE	MANAGEMENT
ENVIRONMENTAL STRUCTURE: REAL OBJECT PICTORIAL DISTORTED REALISTIC SYMBOLIC {AURAL {VISUAL GRAPHICS SCHEMATICS NUMERALS EQUATIONS VERBAL {AURAL {VISUAL WORDS VERBAL SYNTAX	FORMAL PARTIAL RESPONSE RHYMING LITERAL FRAME-STRUCTURE THEMATIC (MEDIATORS) PICTURES CONTEXT SYNONYMS ANTONYMS ANALOGIES RULES INDUCTIVE CUES ASSOCIATIVE CUES	COVERT SELECTIVE CONSTRUCTED VOCAL MOTOR AFFECTIVE	NEED ATTAINMEN- PRESCRIPTIVE ENRICHMEN- MOTIVATION SYSTEMS SUPPOR-

RE: SEQUENCING

VANISHING AND FADING

SUCCESSIVE APPROXIMATIONS; USE OF REINFORCING PROPERTIES OF TERMINAL BEHAVIOR; SMALL STEPS; ADEQUATE PRACTICE

FIGURE 2

* SYNTHESIZED FROM THE PRESENTATION MODEL OF TOSTI AND BALL AND THE CLASSIFICATION OF PROMPTS BY TABER, GLASER AND SCHAEFER

MODEL FOR EVALUATING RESPONSE PAGES IN A PROGRAMMED LEARNING SEQUENCE FOR READING

Assumptions: The population characteristics and social context are known to the evaluator.

PROCEDURE

-----Induce the behavioral objective from the materials.

-----Induce the cognitive skills required to respond to the materials.

-----Analyze the individual frames or groups of frames for:

- .Stimulus
- .Prompts
- .Response
- .Management Elements

See model in figure 2.

****

The purpose of the analysis is to provide the evaluator of curriculum materials with enough information to determine the quality and intensity of learner-interaction required by the materials.

DISCUSSION

In this project, an attempt has been made to extract by observation the objectives, the skills, and the programming techniques implicit or explicit in selected sets of instructional materials of NRS. The materials in question are four separate cassette-tape sequences from Level III of NRS. These materials form only one sequence and a small part of another sequence (that concerned with the teaching of linguistic word patterns) from a total of ten such instructional sequences in the whole of Level III. In turn, these instructional sequences form only one component in the total system. Hence, the analysis performed here is indeed an in-depth one. It deals in a very detailed manner with only a very small sector of one level (out of a proposed 16 levels) of the entire reading system for primary grades.

Man-Machine System

Since the concept of system in educational technology is comparatively new and practically untried, there are no standard methods for assessing the products emerging from the application of a systems approach to the design of instruction. Therefore, in order to clearly understand what has been produced, it is necessary to devise some sort of scheme. The purpose of such a scheme is to enable the observer (examiner) to become aware of the interrelationships within the system and of the types and intensities of the interactions of student with script and response sheet.

Placing the script and response sheet within the context of NRS as a whole should also make the observer (examiner) aware of the invention of a simple but potentially powerful man-machine (child-cassette) learning system. Such consideration should emphasize the broader application of programmed learning which is employed when the concept is extended to encompass an entire system, or better a learning environment. Also evident should be the greater possibility for diversity of materials which a systems approach allows.

The scheme devised for this analysis applies only to the segments of cassette-led instruction not to the system as a whole. However, it is necessary to have some concept of the total system in order to understand and appreciate the scheme used in the in-depth analysis. The purpose of the scheme is to show how and why the materials facilitate learning.

How the Materials Work

The materials work, first of all, by means of criteria or objectives which are derived from a very fine-grain analysis of reading behavior. The objectives extracted from the observation of the materials do match the designer's objectives.

These objectives (see figure 4 as an example) are aimed at very small demonstrations of skills which in combination result in fluent reading behavior. The materials work by triggering student interaction with the voice on the tape and at the same time with the printed and pictorial material on the response sheets. The materials are contructed so as to provide a review or remedial sequence for those who need it. The student also has the option of moving as rapidly as he can through the materials since he operates the machine himself. However, most importantly, the materials work by making available to every student at the appropriate moment the expertise of a master teacher who has designed a rigorous strategy to control student response so as to produce reading skill with maximum effectiveness. Finally, this design should free the classroom teacher for personal roles of interaction with students in the day to day contingencies.

Why the Materials Work

It is difficult to separate the "how" and the "why" in speaking of the operations involved in the use of the materials. However, it is possible to say that the materials work for these reasons:

1) The student knows immediately whether his response was correct.
2) Results are predictable from the very detailed objectives generated for the program.
3) Expert task analysis and careful design and editing have preceded production.

SEQUENCE 3-1-A

OBJECTIVES AS STATED BY THE DESIGNER.	OBJECTIVES EXTRACTED THROUGH ANALYSIS OF MATERIALS
1. READS ISOLATED GRAPHEME/ PHONEME : CH - /CH/	1. STUDENT WILL ASSOCIATE THE SOUND /CH/ WITH THE LETTER SYMBOLS CH.
2. READ CH IN PRINTED WORDS; SEES, HEARS, READS WORD; MARKS GRAPHEME	2. THE STUDENT WILL ASSOCIATE THE SOUND /CH/ WITH THE LETTER SYMBOLS CH AS THESE APPEAR AT THE BEGINNING AND END OF WORDS.
3. SEES, HEARS, IDENTIFIES ONE WORD; READS CH	3. THE STUDENT WILL READ WORDS WITH /CH/ SEPARATELY AND IN SENTENCES.
4. SEES, HEARS, READS /CH/ IN SENTENCES; MARKS SPECIFIED /CH/ WORDS.	

FIGURE 4

4) Small skills are very carefully sequenced, then combined, and finally practiced to give fluency.

5) Careful concideration has been given to knowledge of population (learner) characteristics and the type of environment most conducive to the learning of these skills.

Finally, the materials work by means of rigor and pay-off for the learner.

The Scheme

The scheme has been devised only for analysis of response sheets with accompanying cassette-tape. Greater emphasis has been placed on the response sheet than on the script. The tape does, however, serve a vital function in the cassette-led instruction and its importance should be pointed up here. Research has shown that children of kindergarten age learn to read better when they have a model; i.e., these children benefit in a special way from listening to oral reading. The scheme is complete for the purpose for which it was devised. However, its limitation is that it allows the analyst to look at only a limited segment of the system and that it has not drawn sufficient attention to the oral presentation techniques on the tapes. A much more complex scheme is needed to view the system in all of its interrelationships.

The scheme does serve to show that the purpose ofthe study was accomplished. Concurrent validity was establsshed between the objectives and skills observed through the materials and those presented in theory by the designer.

CONCLUSIONS

_____ A careful analysis of the materials for the use of programming techniques reveals both variety of type of response as well as careful sequencing in order to guide the learner to the achievement of the learning objective.

_____ Not only have scientific principles of programming been employed but they have been used with the artistry that is needed to produce a successful program.

_____ Attention has been paid not only to cognitive skills but also to the affective types of responses.

_____ The use of the tape-cassette enables the child to learn from listening to a skilled reader who "can convey more meaning than an unskilled reader can grasp for himself even in identical words."

_____ The use of the tape recorder also capitalizes on the child's spoken vocabulary in a special way.

_____ NRS gives evidence of the value of a broader concept of programming than that of programmed books.

Possibilities for Further Study

_____ Since a systems design changes the role of the classroom teacher, further analyses could be performed to delineate appropriate teacher behaviors, especially those involving the applications of psychological principles and interpersonal relationships within the classroom setting.

_____ Studies in concept formation related to the developmental level of the child may provide valuable information for more skillful instructional design.

_____ Studies in greater depth and extensiveness could be done on the utilization of systems conventions in a man-machine system.

_____ Studies could be done to produce criteria for: relevancy of response, "problem" worth of sequences, and probability of success of given sequences.

_____ Studies could be done to determine the existence of appropriate practice conditions in sequences of instruction (Zita Glasgow, 1972).

Concluding Comments.

Where prediction becomes more precise, a correspondingly precise method of evaluation for decision-making becomes mandatory. One type of evaluation occurs during and after actual use of materials by students. However, another type of evaluation should occur before the materials are completed for production and this same type of evaluation should be capable of being performed by/for potential users or buyers of materials. Ultimately a scheme such as the one presented here might be perfected to serve such a function. In the future, instructional technologists, engineers and analysts will be needed to perform evaluative operations on instructional systems and on the materials which form essential components of these systems.

NOTES

1. Richmond, W. Kenneth, ed. *The Concept of Educational Technology*. London: Weidenfelf and Nicolson, 1970, 153.

2. Beck, Isabel L. and Donna D. Mitroff. *The Rationale and Design of a Primary Grades Reading System for an Individualized Classroom*. Pittsburgh: Learning Research and Development Center, 1972, 26.

3. ibid., 19.

4. ibid., 40.

5. ibid., 55.

6. Richmond, op. cit., 5.

7. Glaser, Robert and Lauren B. Resnick. "Instructional Psychology". *Annual Review of Psychology*, Vol. 23, 1972, 206.

8. ibid.

9. Krathwohl, David R. and David A. Payne. "Defining and Assessing Educational Objectives" in Robert L. Thorndike, ed., *Educational Measurement*. Washington, D.C.: American Council on Education, 1971, 21.

10. Callender, Patricia. *Programmed Learning: Its Development and Structure.* London: Longmans, Green and Co., Ltd., 1969, 16.

11. Glaser, Robert. "The Psychology of Programmed Instruction" in *International Conference on Programed Instruction*, Berlin, 1963, 194.

12. Hughes, Marie in *Teaching Strategies and Cognitive Functioning in Elementary School Children* by Hilda Taba, 1966, 24.

13. Richmond, op. cit., 137.

14. Lumsdaine in *Theories of Learning and Instruction*, NSSE. Chicago: University of Chicago Press, 1964, 175.

NOTES (continued)

15. Taber, Julian, Robert Glaser and Halmuth H. Schaefer. Learning and Programmed Instruction. Reading, Mass.: Addison-Wesley, 1965, 19.

16. ibid., 91.

17. Merrill, David M., ed. Instructional Design: Readings. Englewood cliffs, New Jersey: Prentice-Hall, Inc., 1971, "The Analysis of Instructional Objectives" by Robert M. Gagne, 113.

18. ibid., 113.

19. ibid., 123.

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Merrill, M. David, ed. Instructional Desigh: Readings. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971.

Mueller, Theodore H., ed. Proceedings of the Seminar on Programmed Learning. New York: Appleton-Century-Crofts, 1968.

Richmond, W. Kenneth, ed. The Concept of Educational Technology. London: Weidenfelf and Nicolson, 1970.

Rothkopf, Ernst Z. and Paul E. Johnson, ed. Verbal Learning Research and the Technology of Written Instruction. Teachers College, Columbia University: Teachers College Press, 1971.

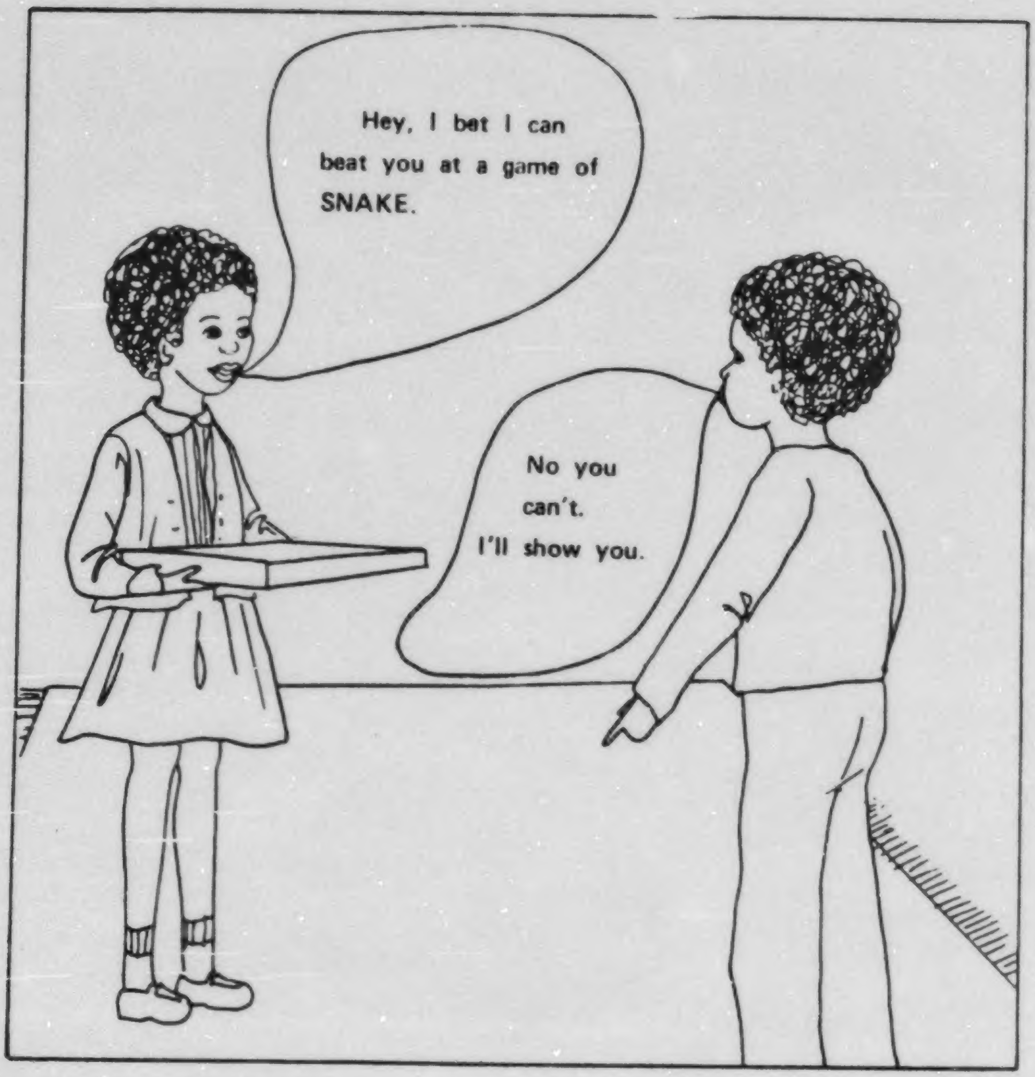
Taber, Julian I., Robert Glaser and Halmuth H. Schaefer. Learning and Programmed Instruction. Reading, Mass.: Addison-Wesley, 1965.

Tosti, Donald and John R. Ball. "A Behavioral Approach to Instructional Design and Media Selection". AV Communication Review, Vol. 17, No. 1, Spring 1969.

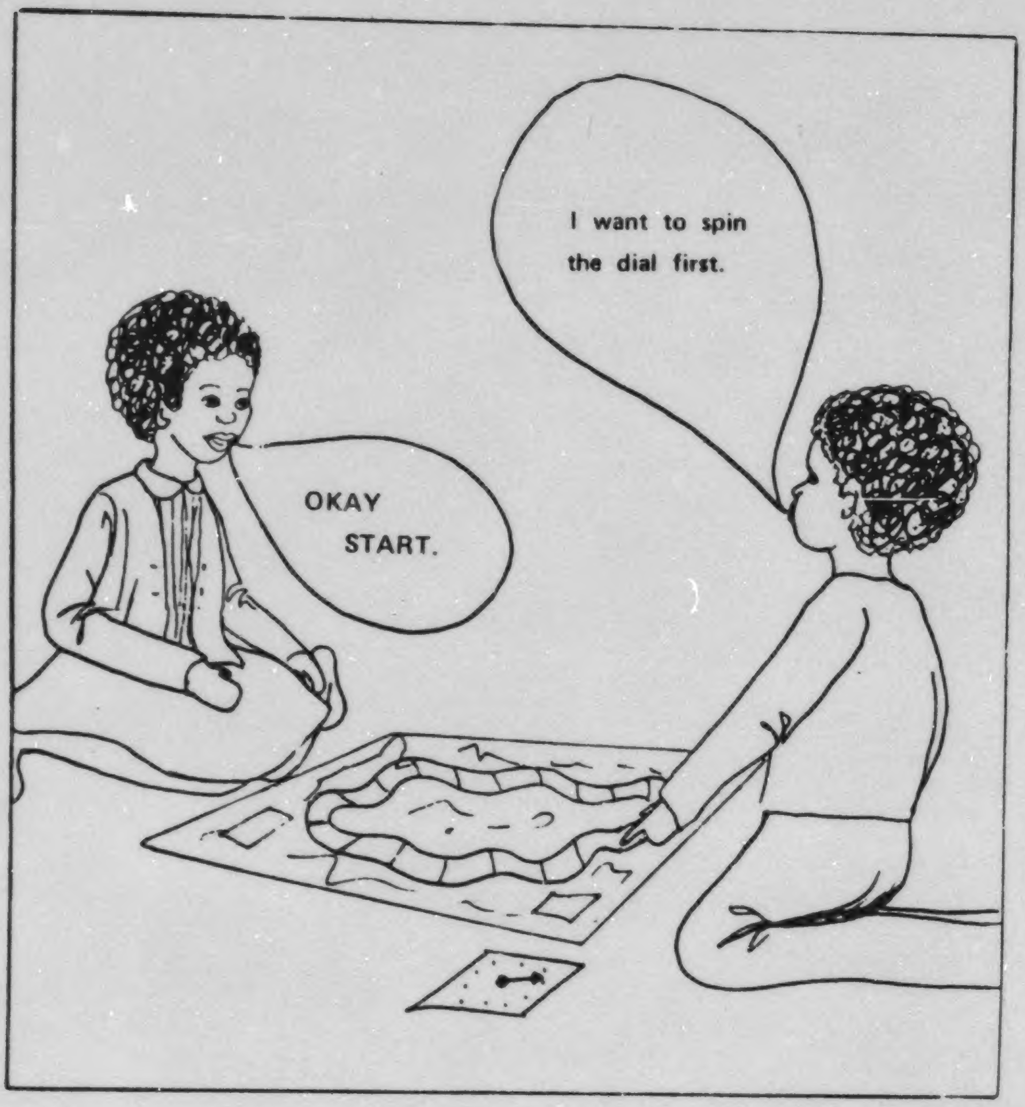
Cartoons designed by Tommye Whiting, (during her internship at Frick School,) to test and teach observation and analysis of social interaction. The cartoons are part of an instructional sequence developed for third grade social studies.

" SMART LISA AND JIVE KENNY "

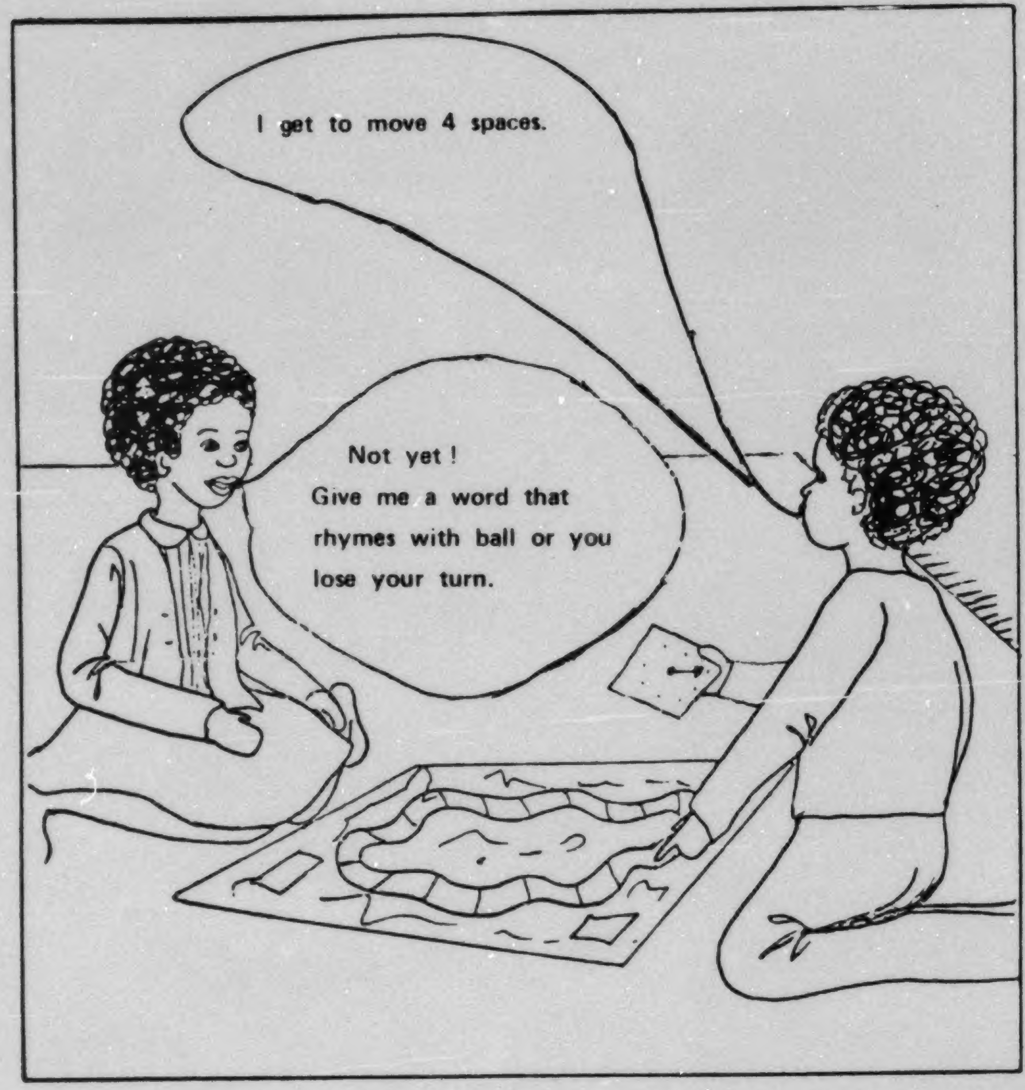
I


Hey, I bet I can beat you at a game of SNAKE.
No you can't. I'll show you.

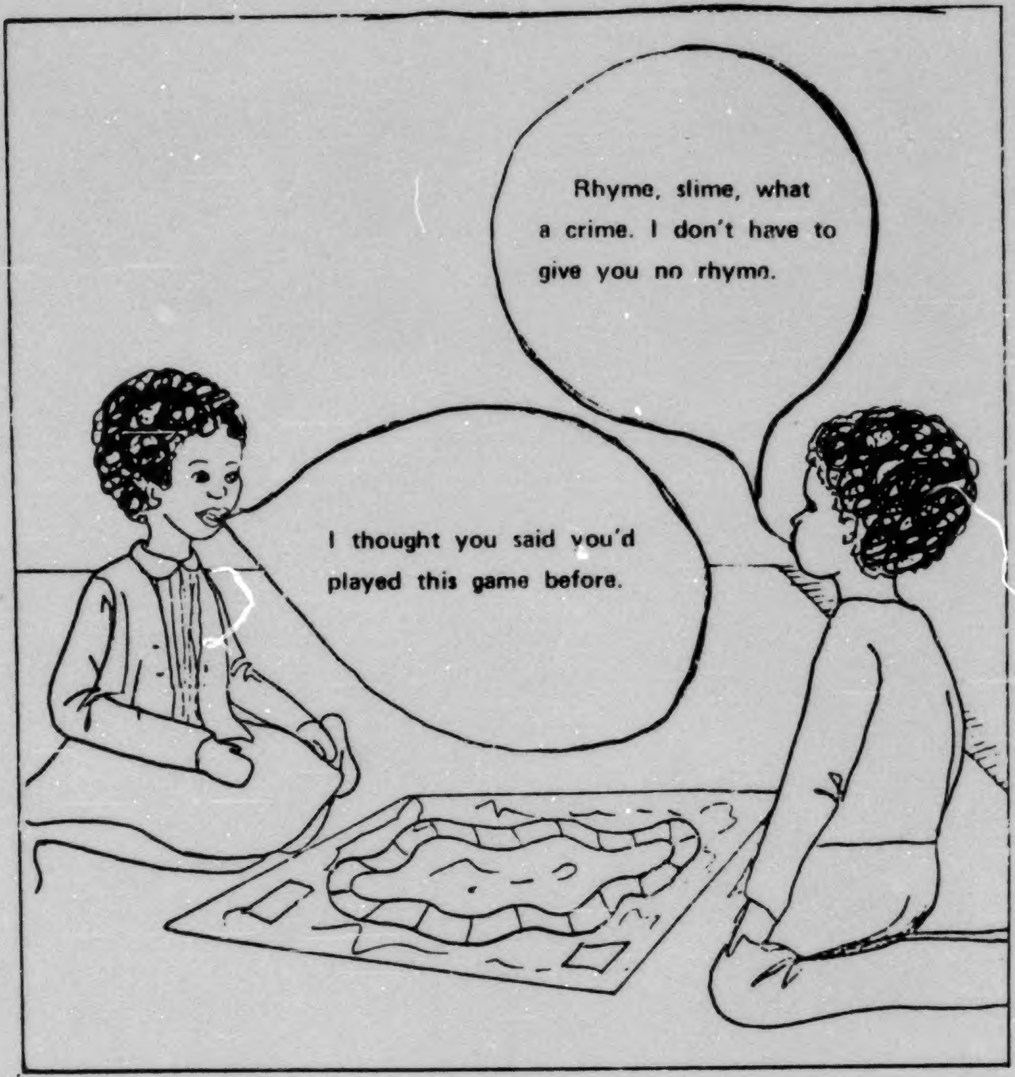
1


I want to spin the dial first.
OKAY START.

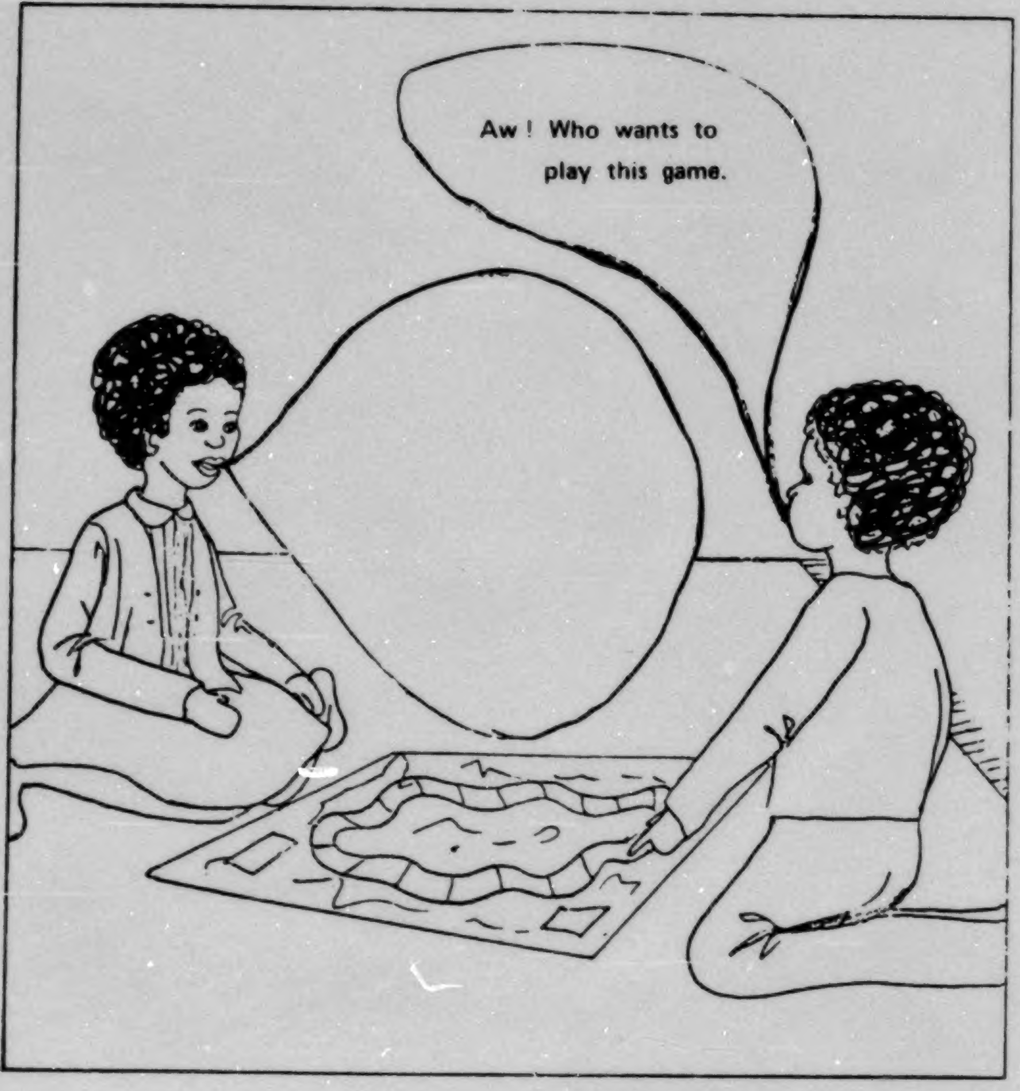
2


I get to move 4 spaces.
Not yet! Give me a word that rhymes with ball or you lose your turn.

3


Rhyme, slime, what a crime. I don't have to give you no rhyme.
I thought you said you'd played this game before.

4

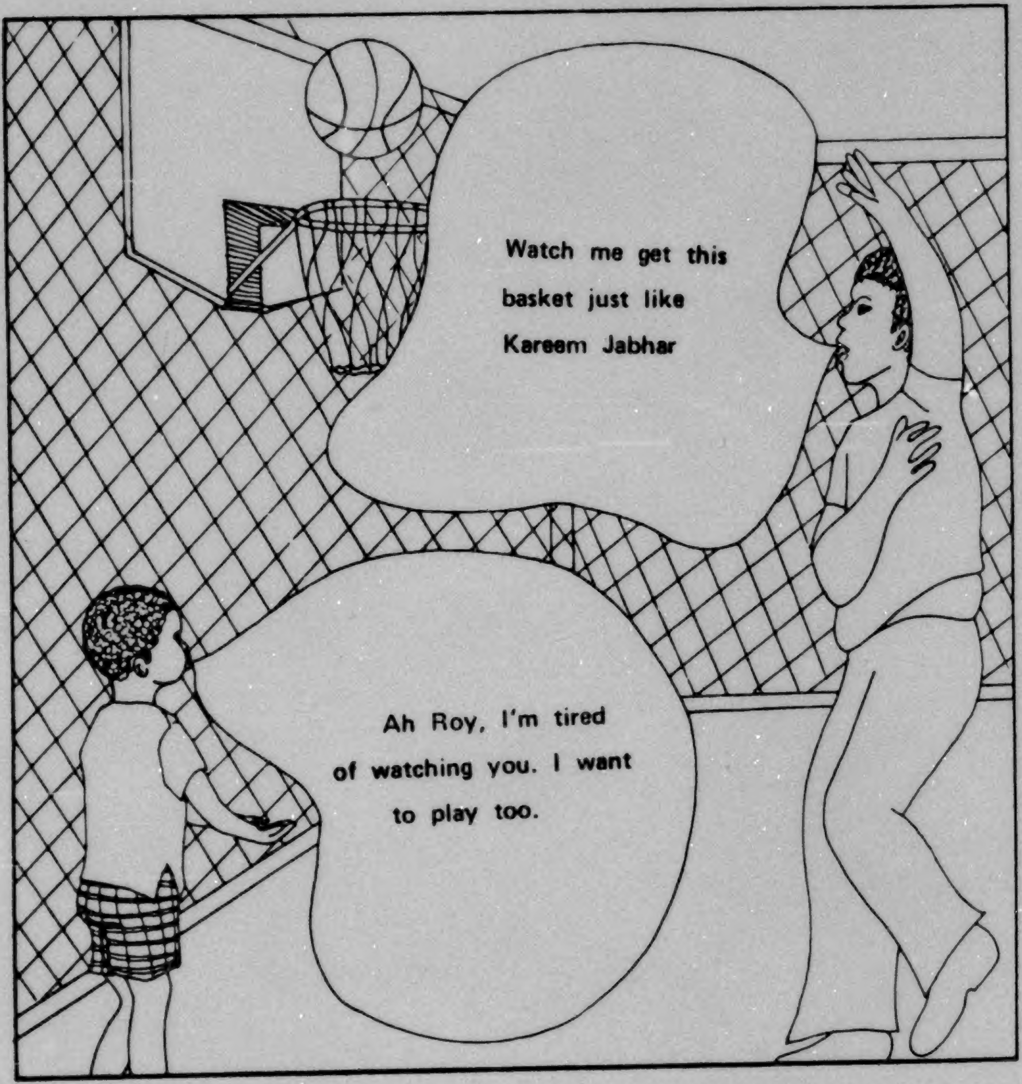

Aw! Who wants to play this game.

Now fill in what you think Smart Lisa is saying.

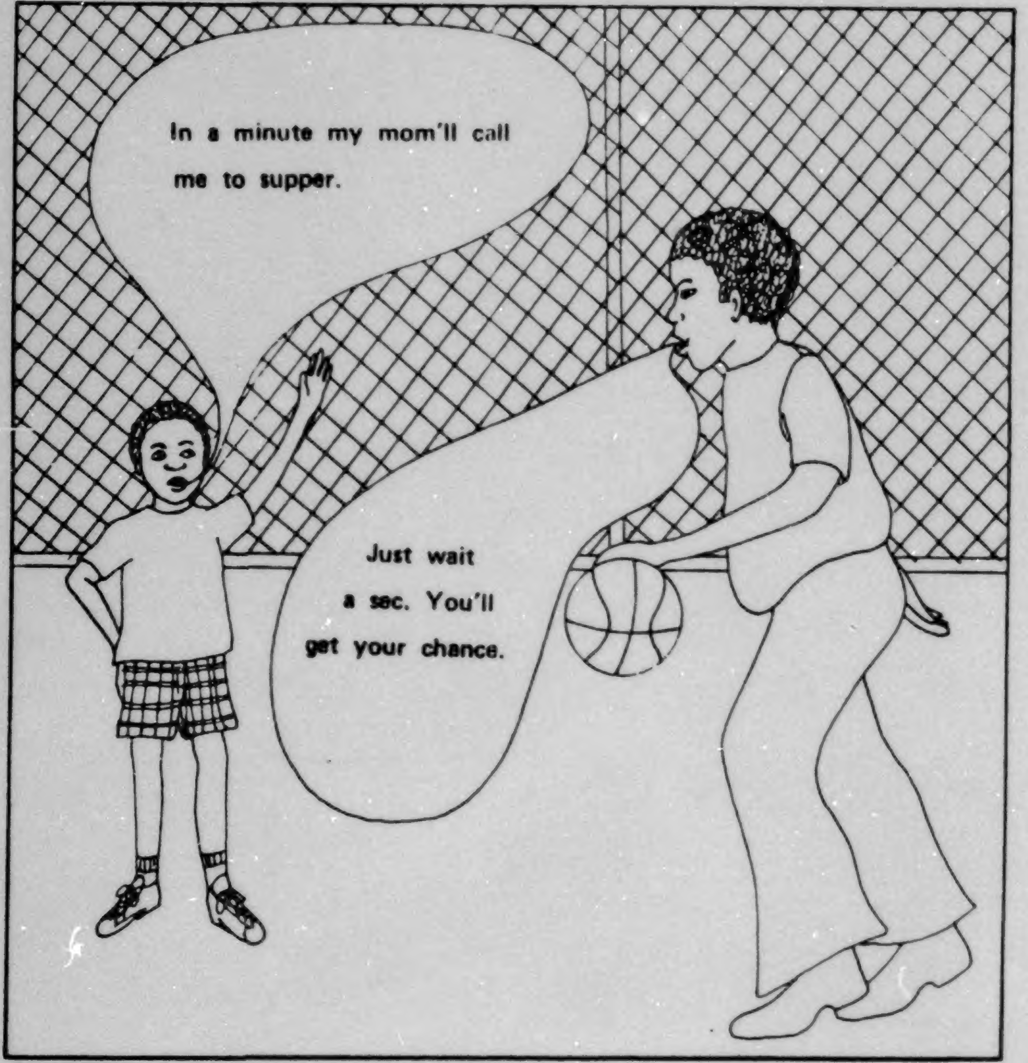
5

" BIG ROY AND LITTLE JOHN "

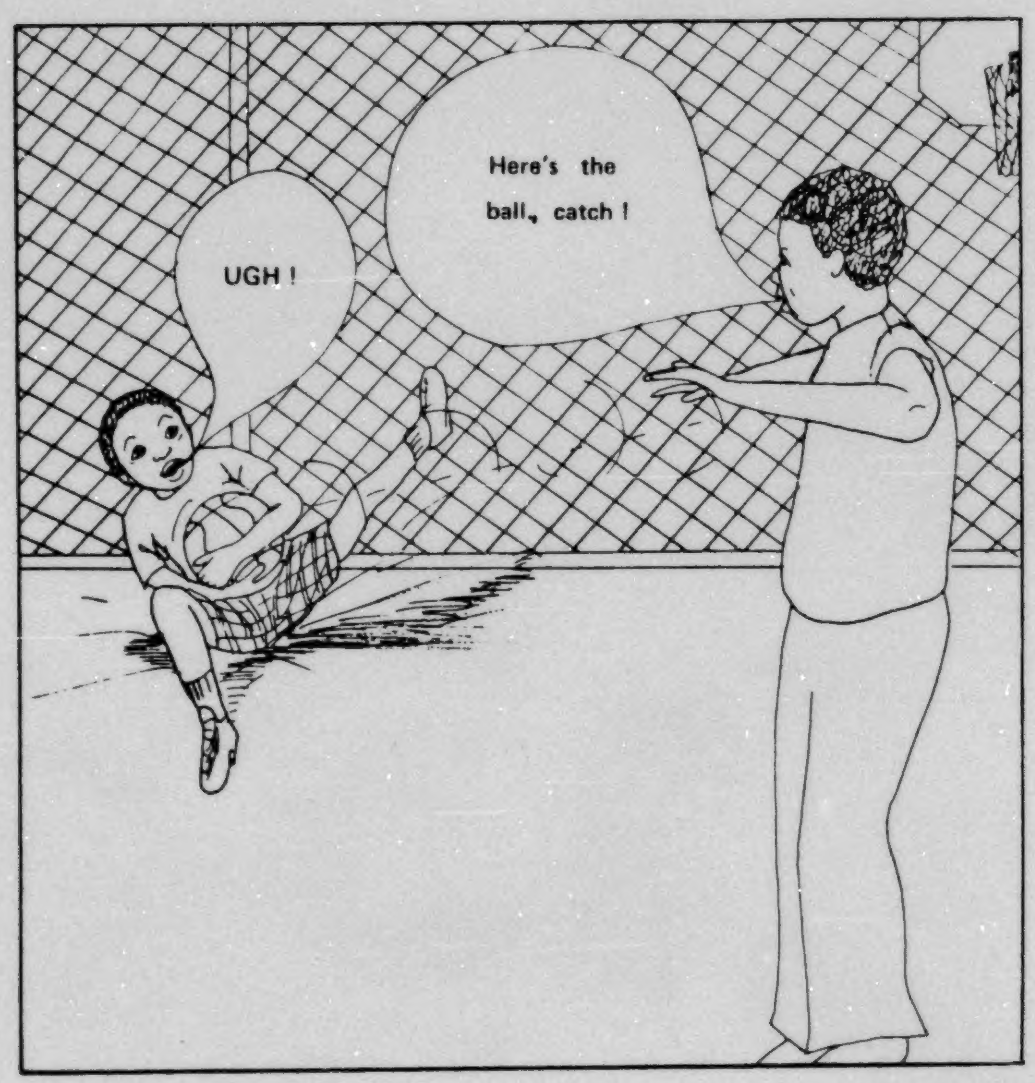
II


Watch me get this basket just like Kareem Jabhar
Ah Roy, I'm tired of watching you. I want to play too.

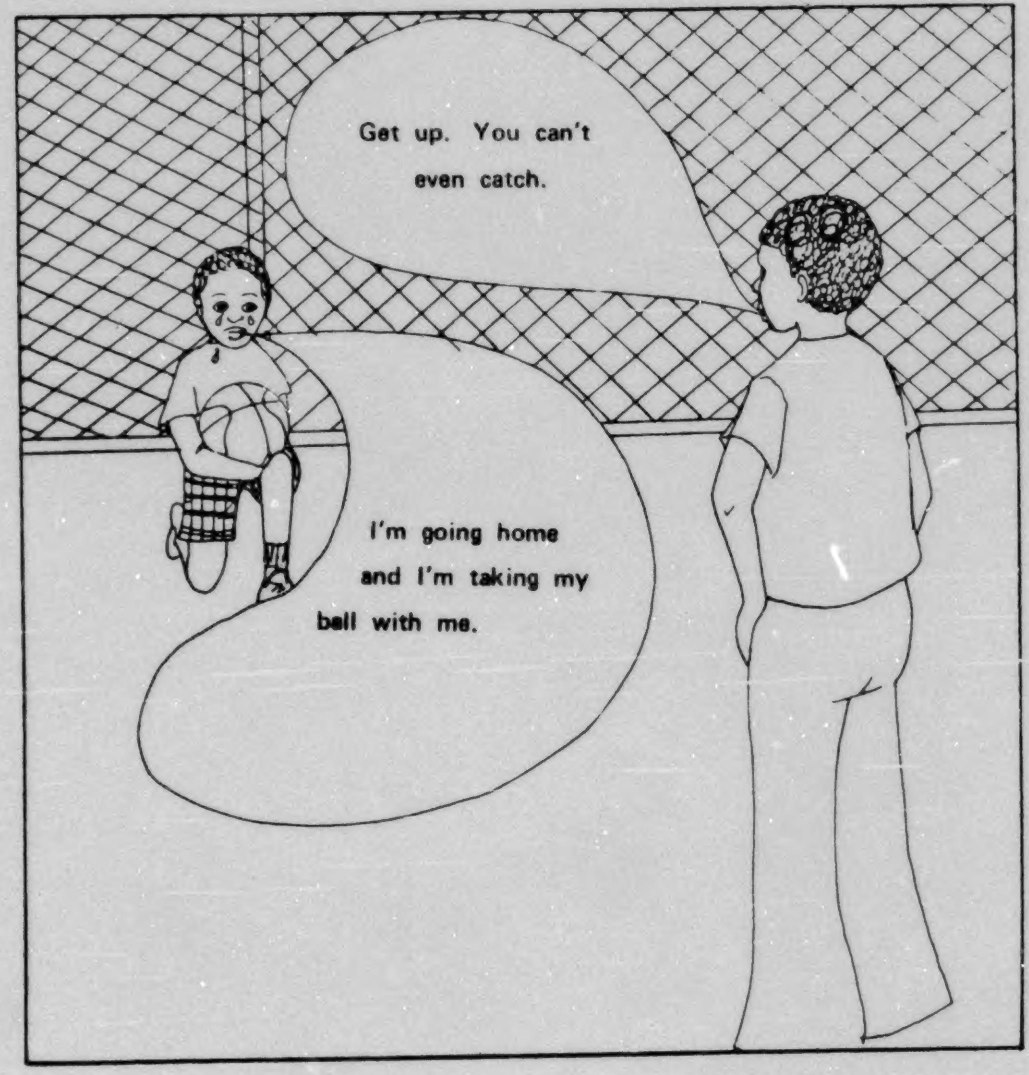
1


In a minute my mom'll call me to supper.
Just wait a sec. You'll get your chance.

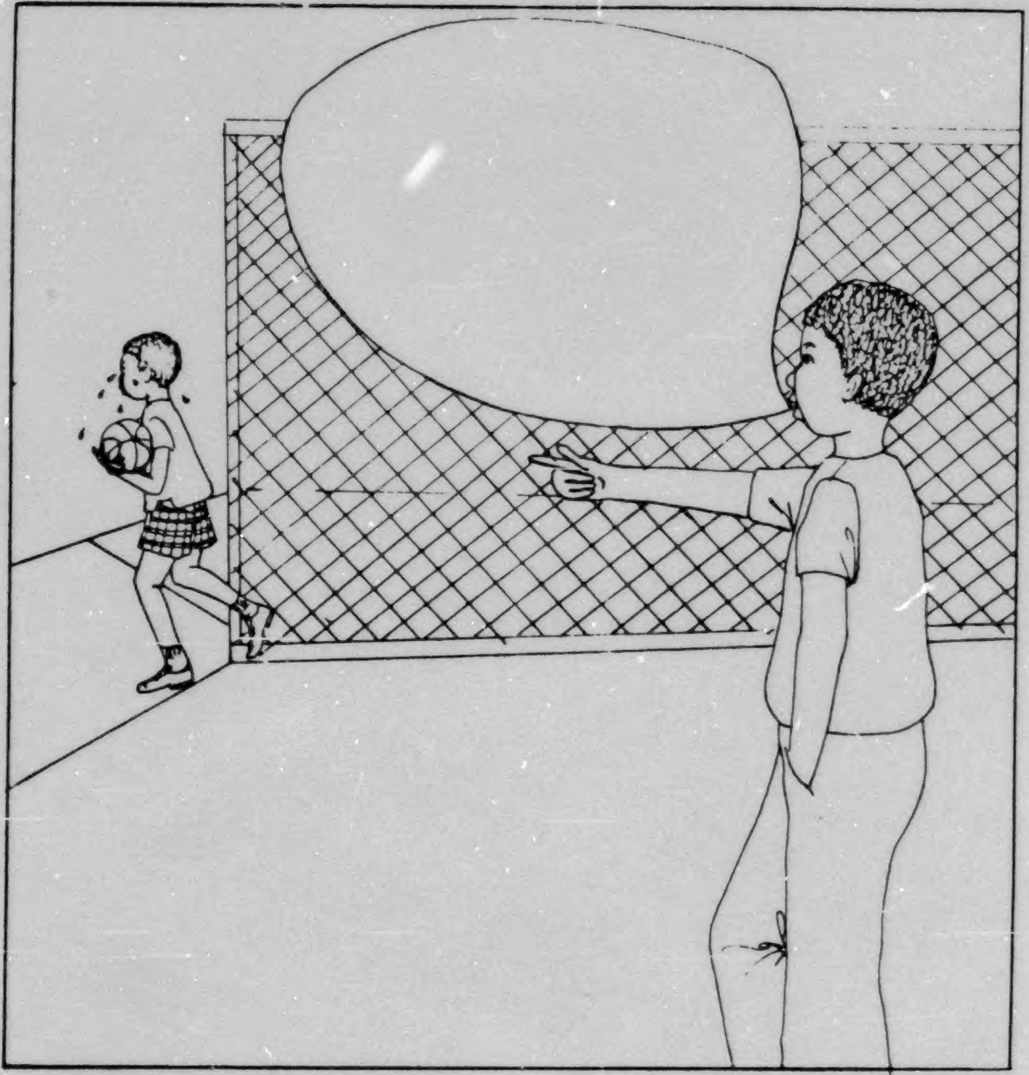
2


Here's the ball, catch !
UGH !

3


Get up. You can't even catch.
I'm going home and I'm taking my ball with me.

4

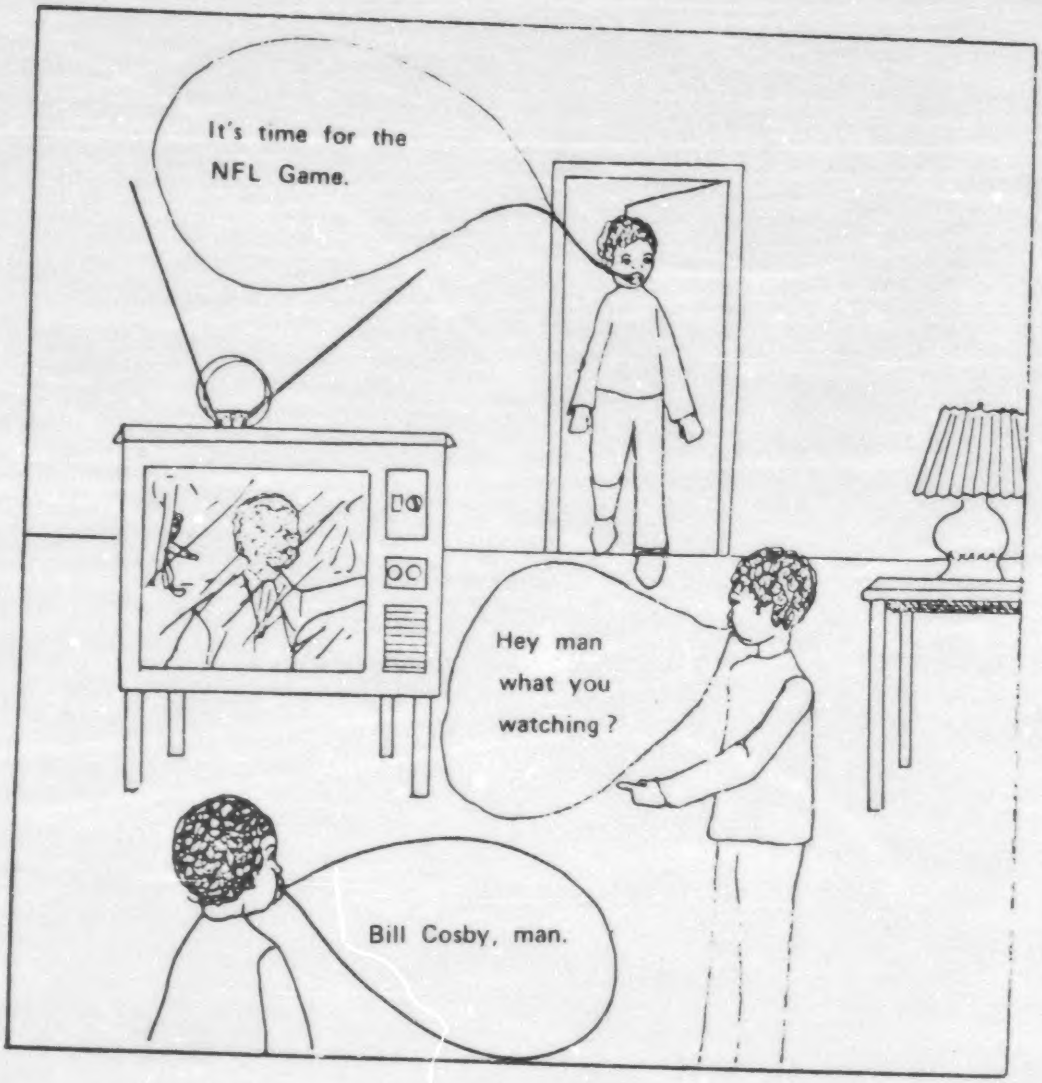


Now fill in what you think Big Roy is saying :

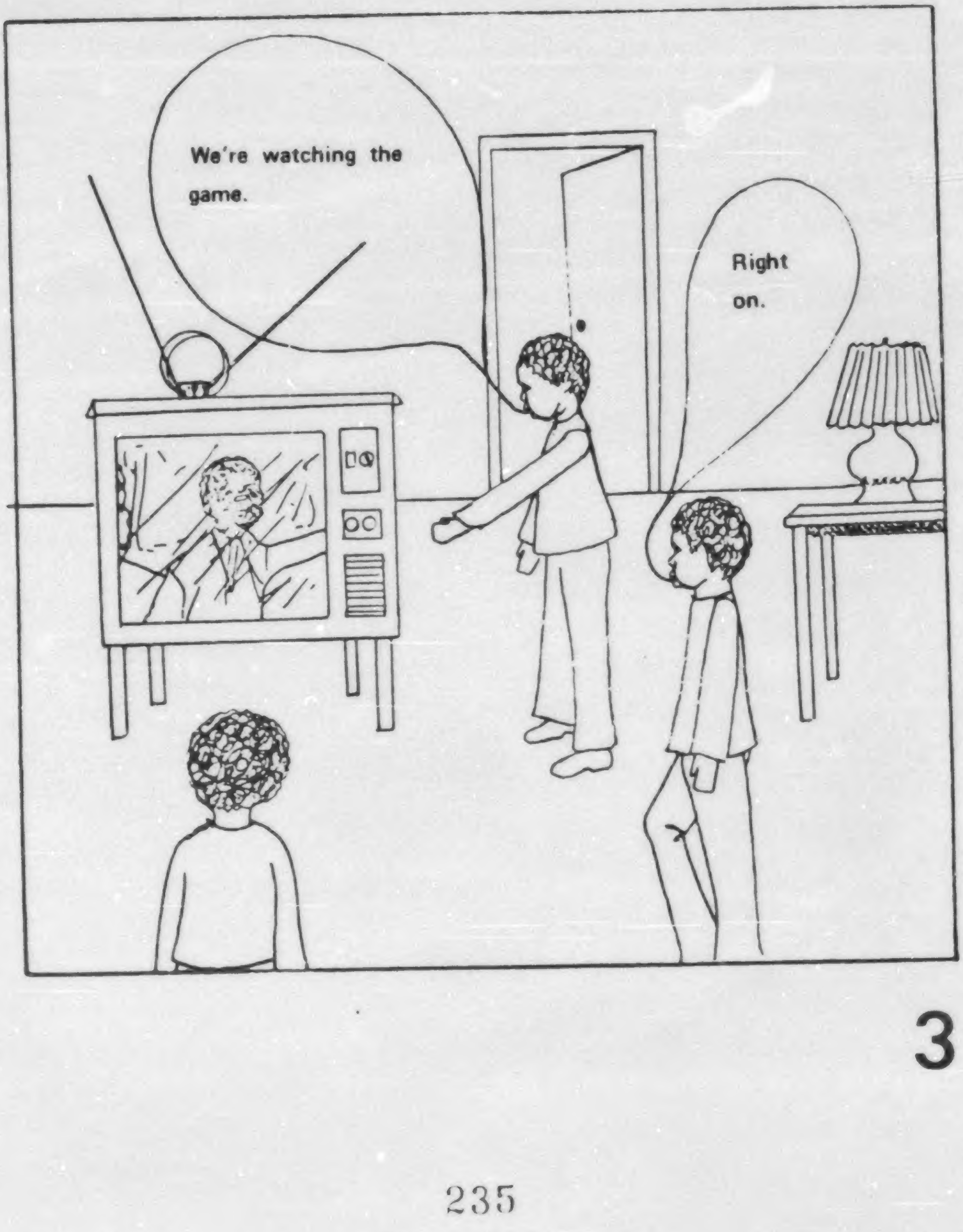
5

" T. V. MADNESS"

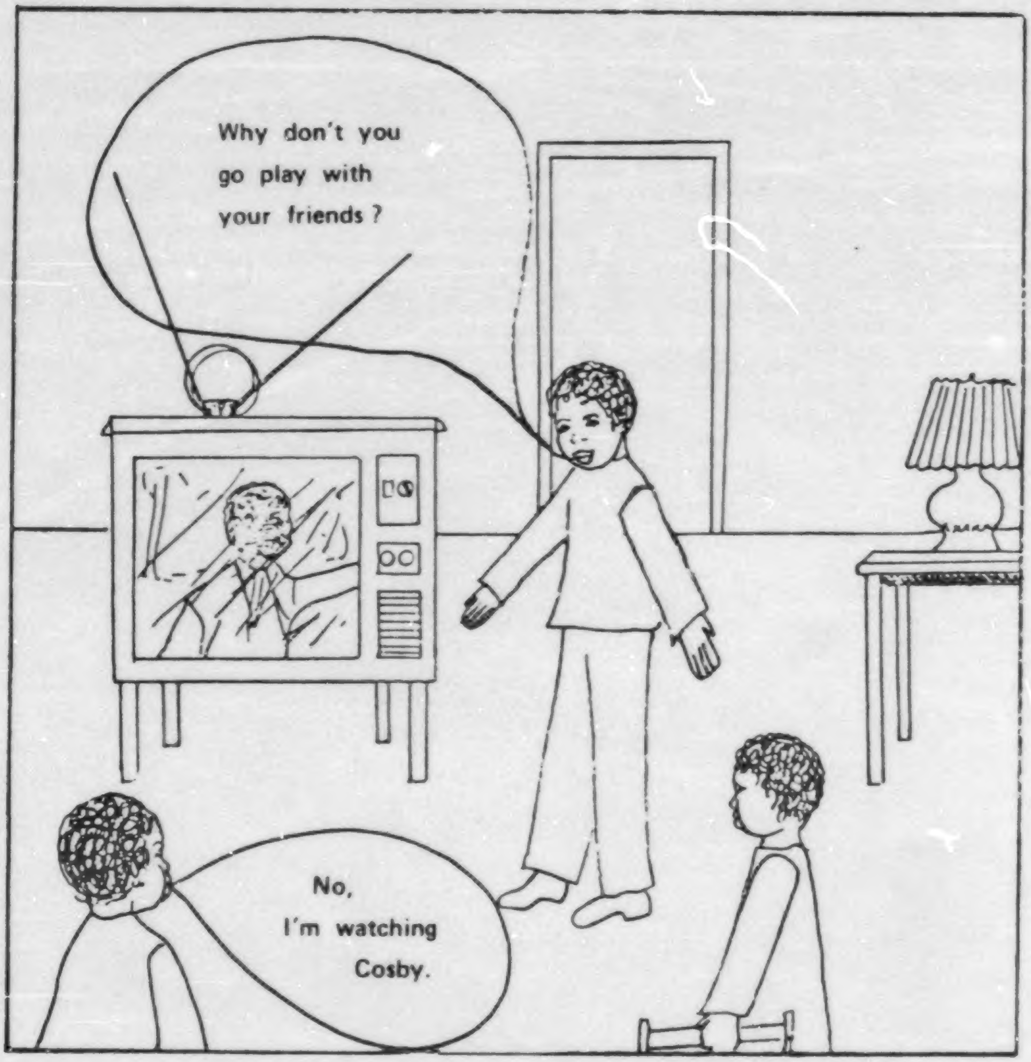
III


It's time for the NFL Game.
Hey man what you watching?
Bill Cosby, man.

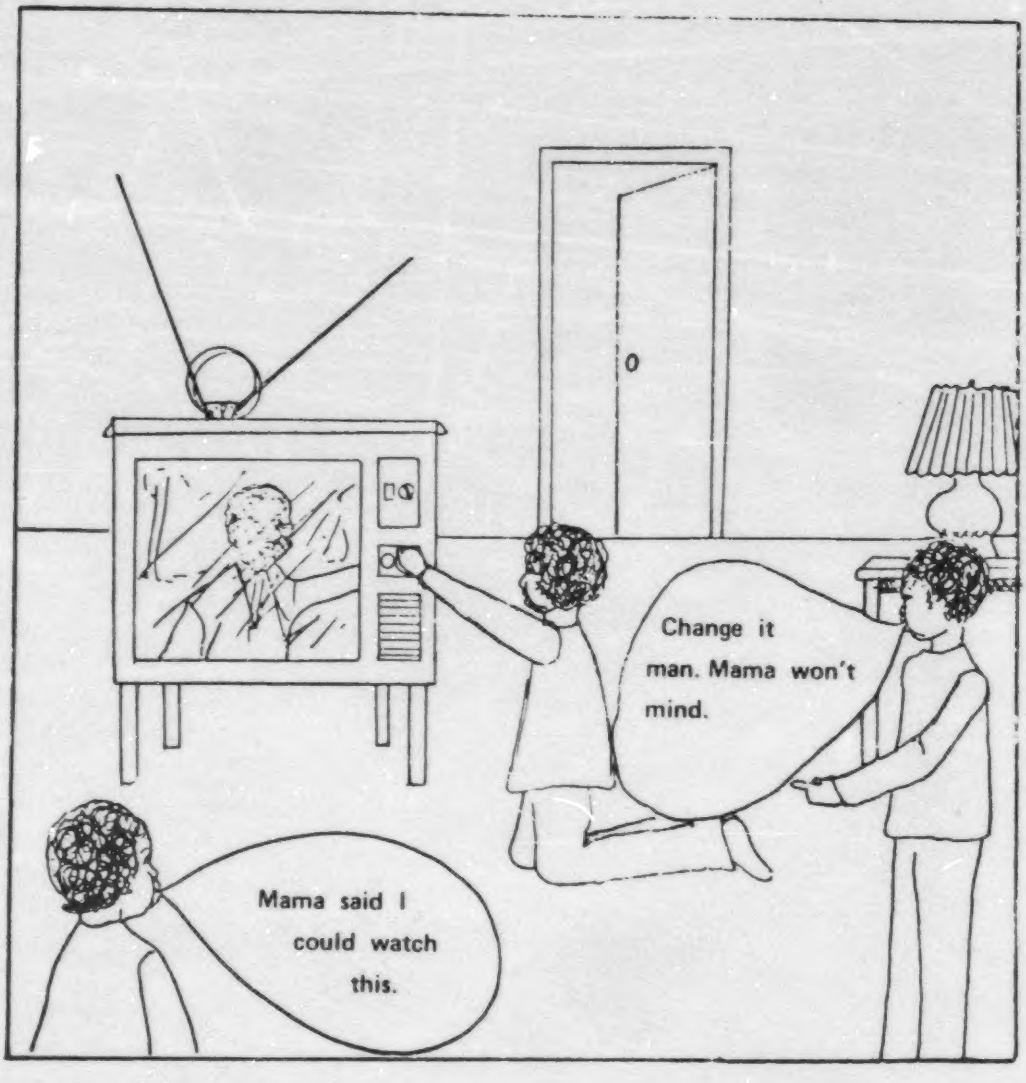
2


We're watching the game.
Right on.

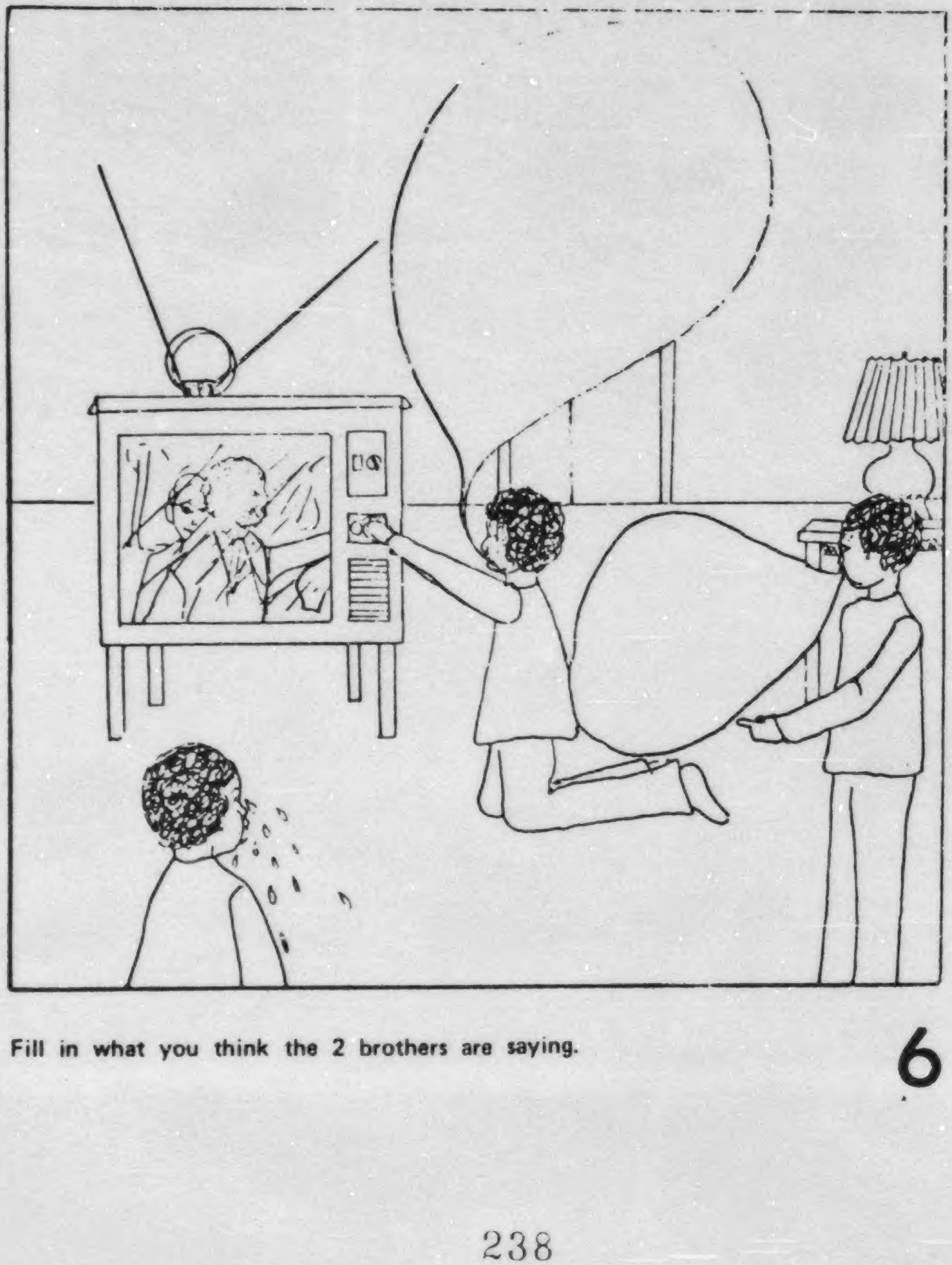
3


Why don't you go play with your friends?
No, I'm watching Cosby.

4


Change it man. Mama won't mind.
Mama said I could watch this.

5

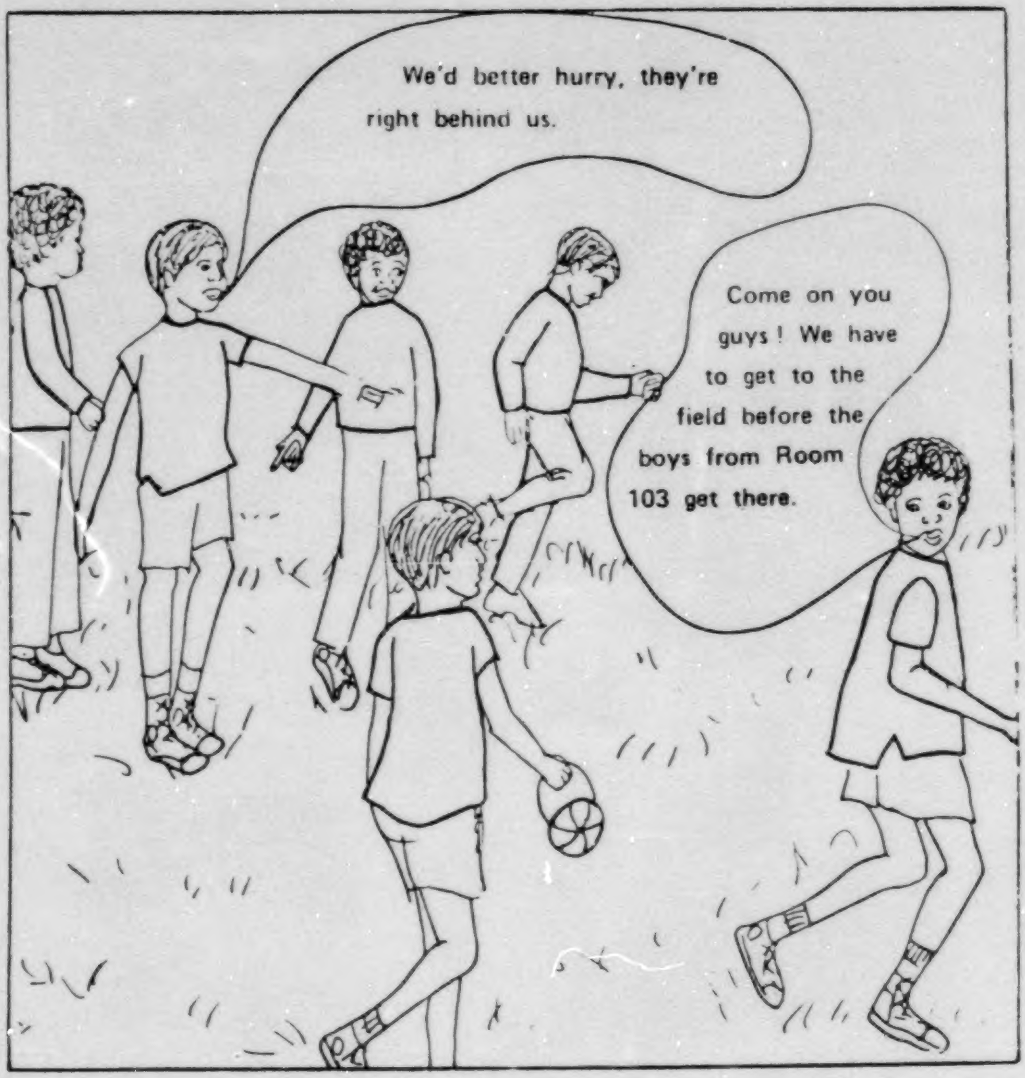


Fill in what you think the 2 brothers are saying.

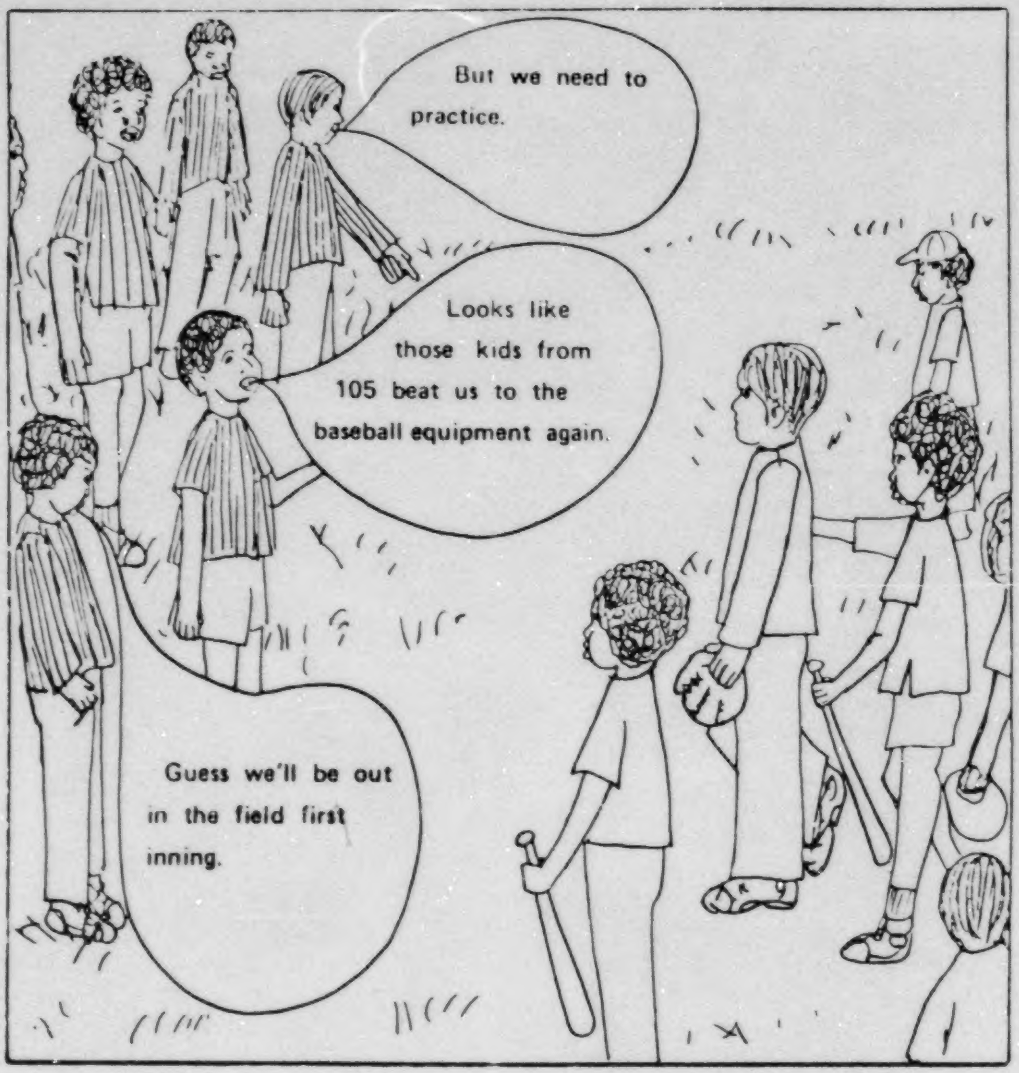
6

" THE BIG GAME "

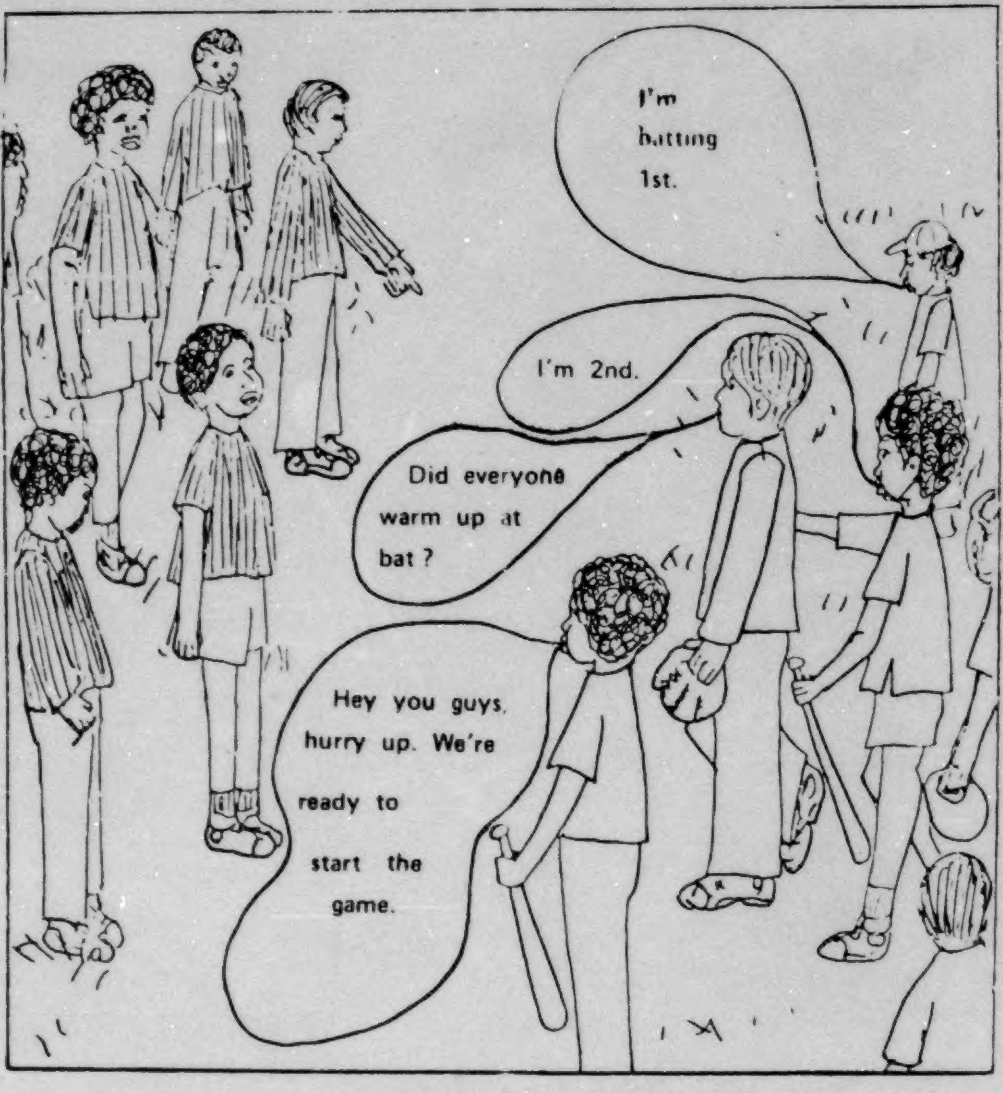
IV


We'd better hurry, they're right behind us.
Come on you guys! We have to get to the field before the boys from Room 103 get there.

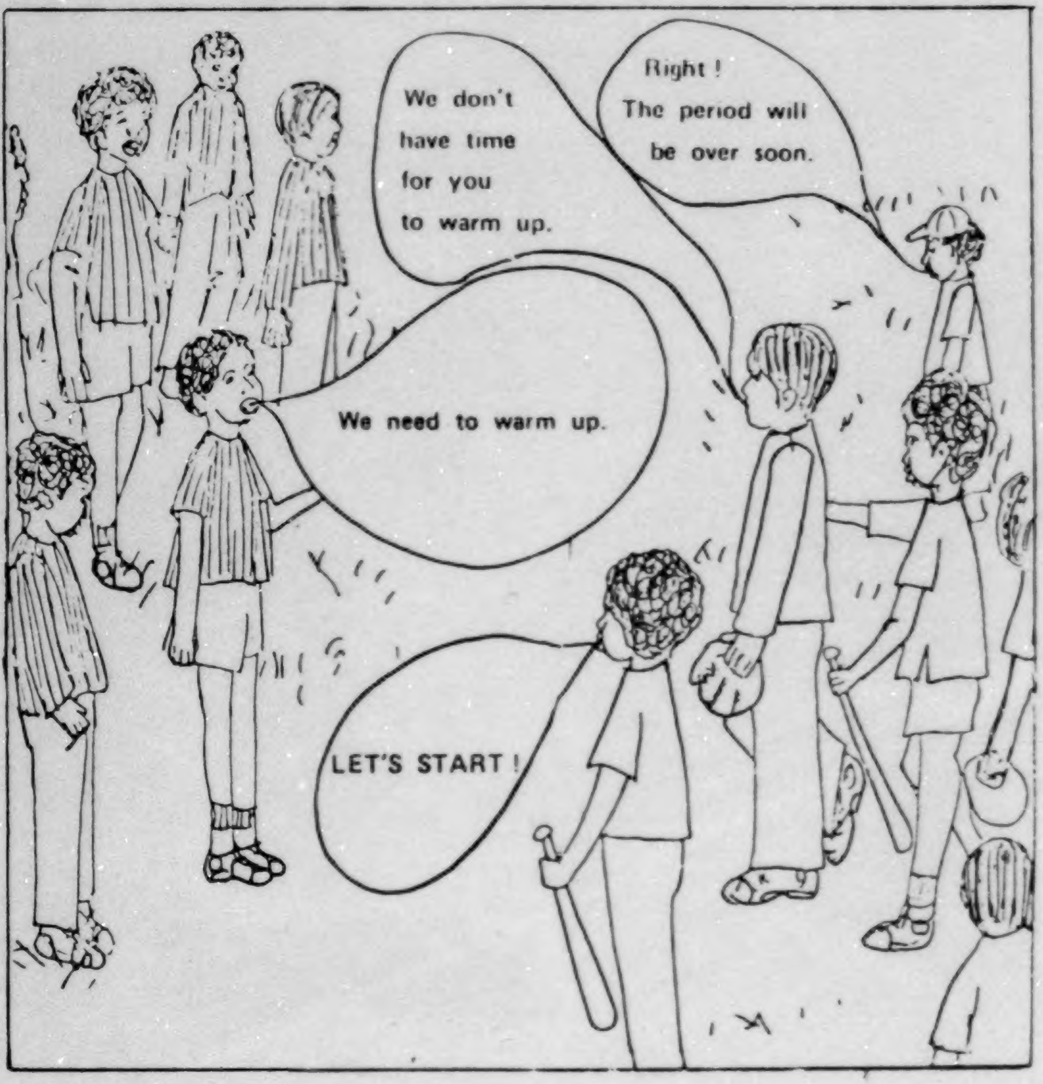
1


But we need to practice.
Looks like those kids from 105 beat us to the baseball equipment again.
Guess we'll be out in the field first inning.

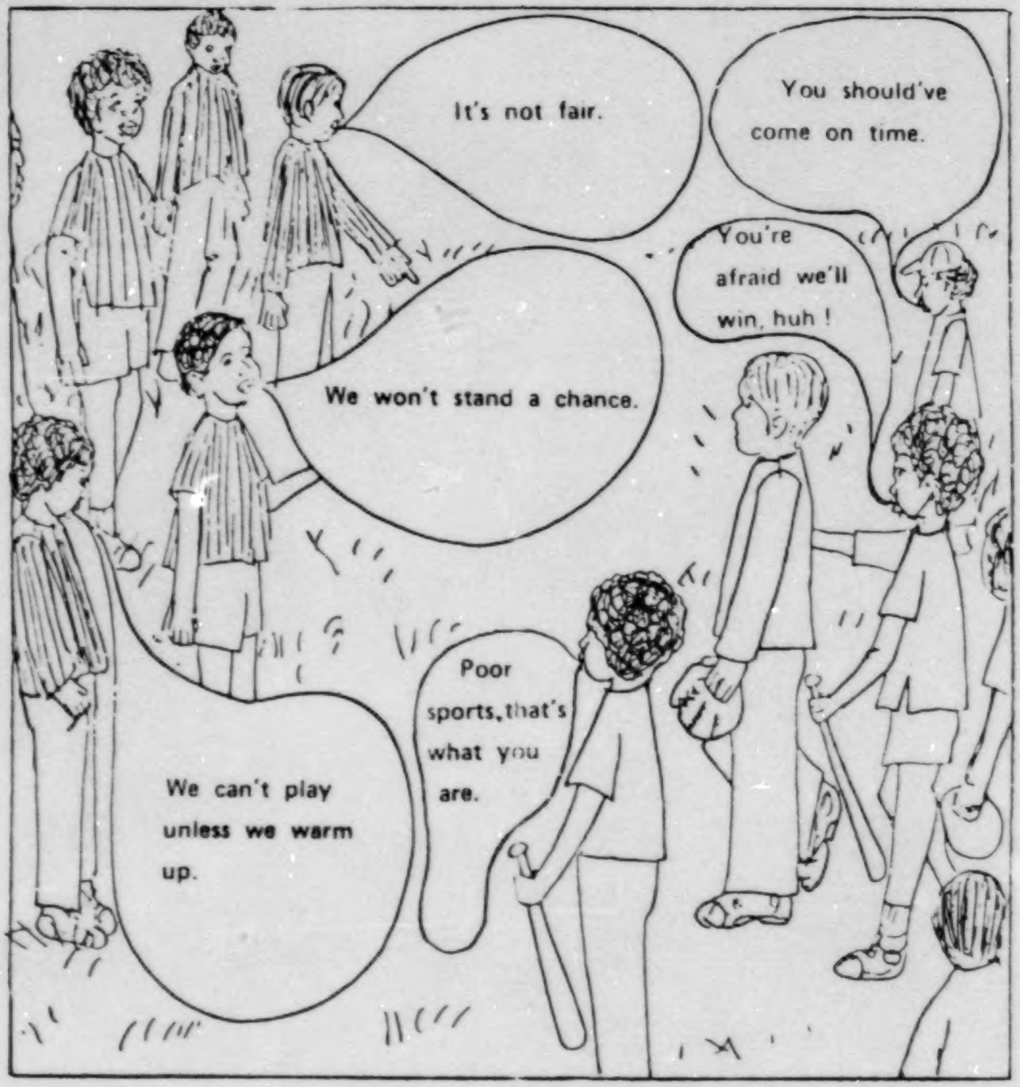
2


I'm hatting 1st.
I'm 2nd.
Did everyone warm up at bat?
Hey you guys, hurry up. We're ready to start the game.

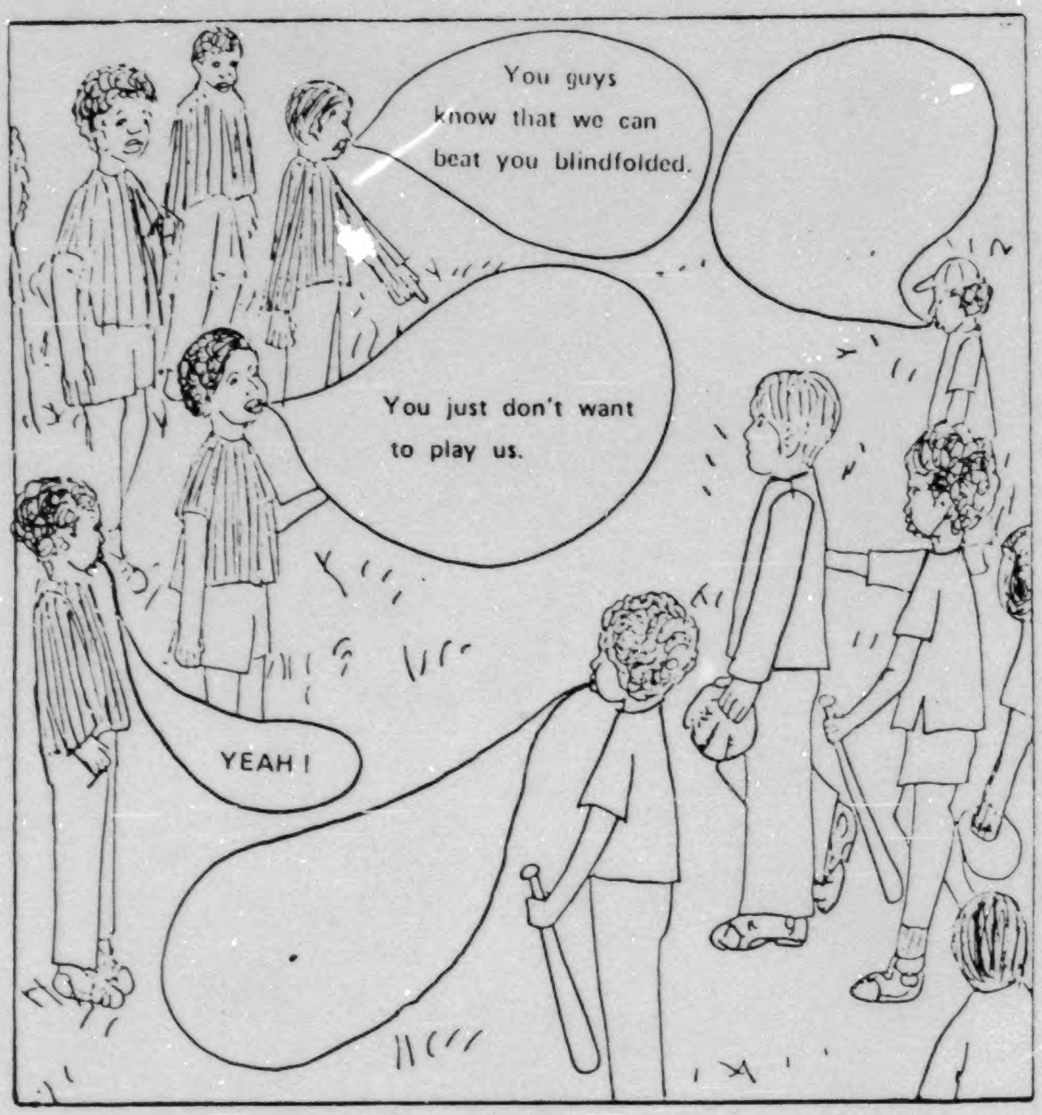
3


We don't have time for you to warm up.
Right! The period will be over soon.
We need to warm up.
LET'S START!

4


It's not fair.
You should've come on time.
You're afraid we'll win, huh !
We won't stand a chance.
Poor sports, that's what you are.
We can't play unless we warm up.

5

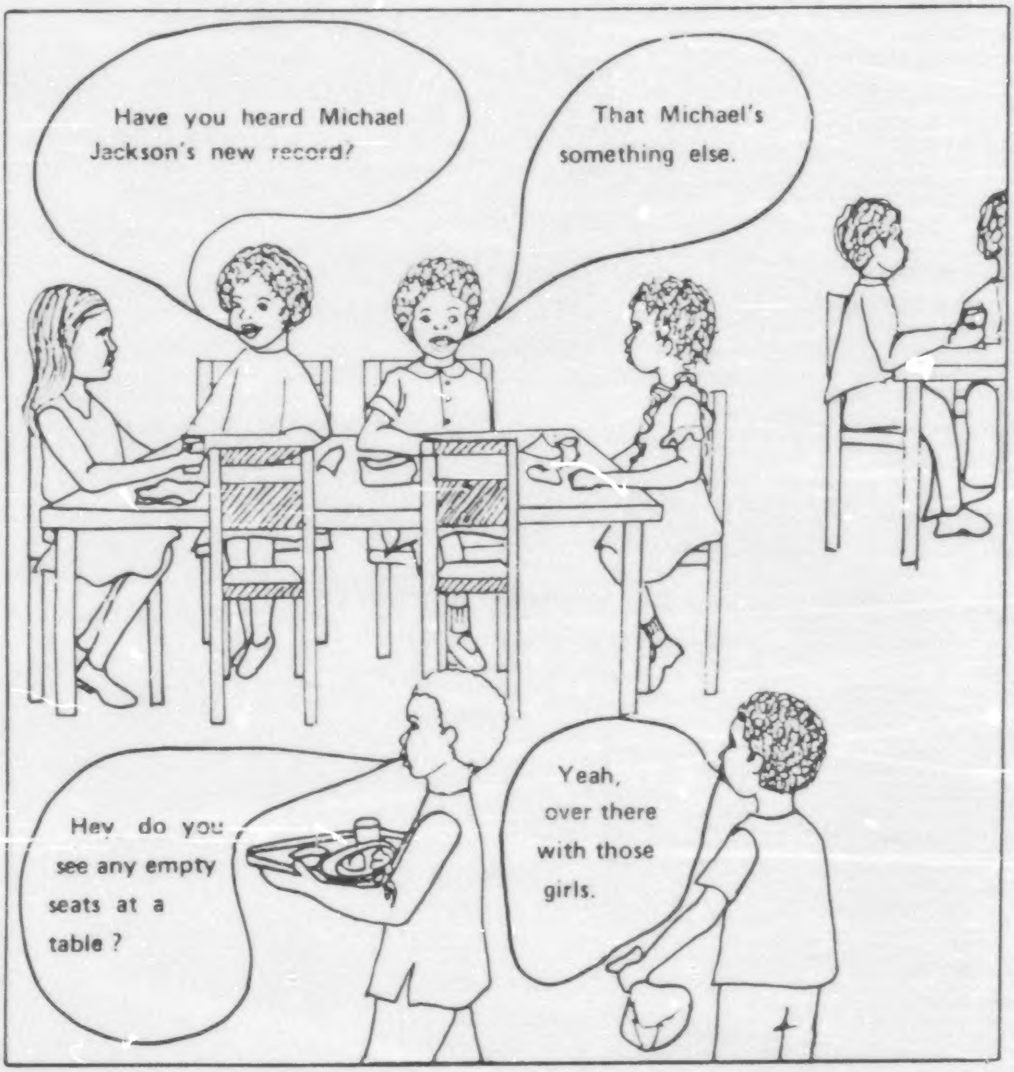

You guys know that we can beat you blindfolded.
You just don't want to play us.
YEAH !

Now fill in what you think the boys from 105 are saying :

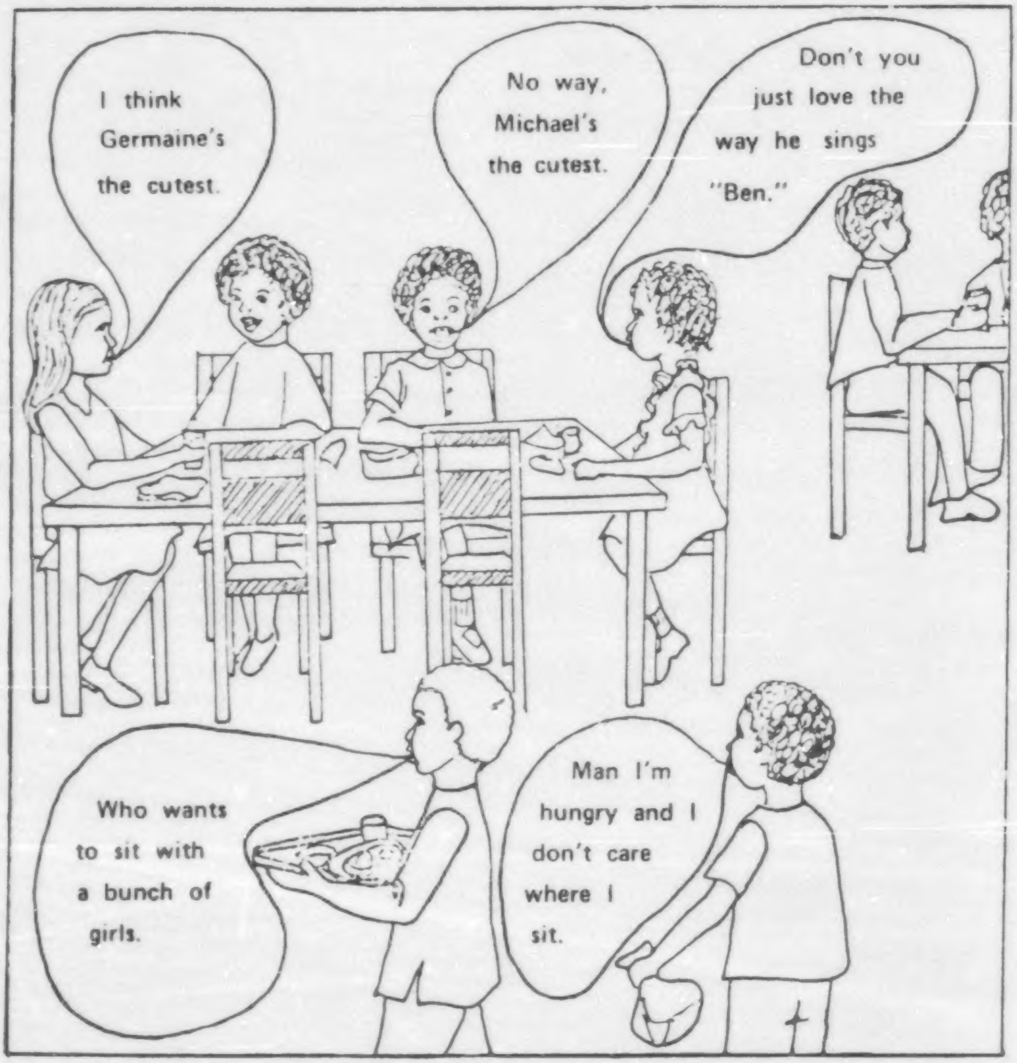
6

" LUNCH TALK "

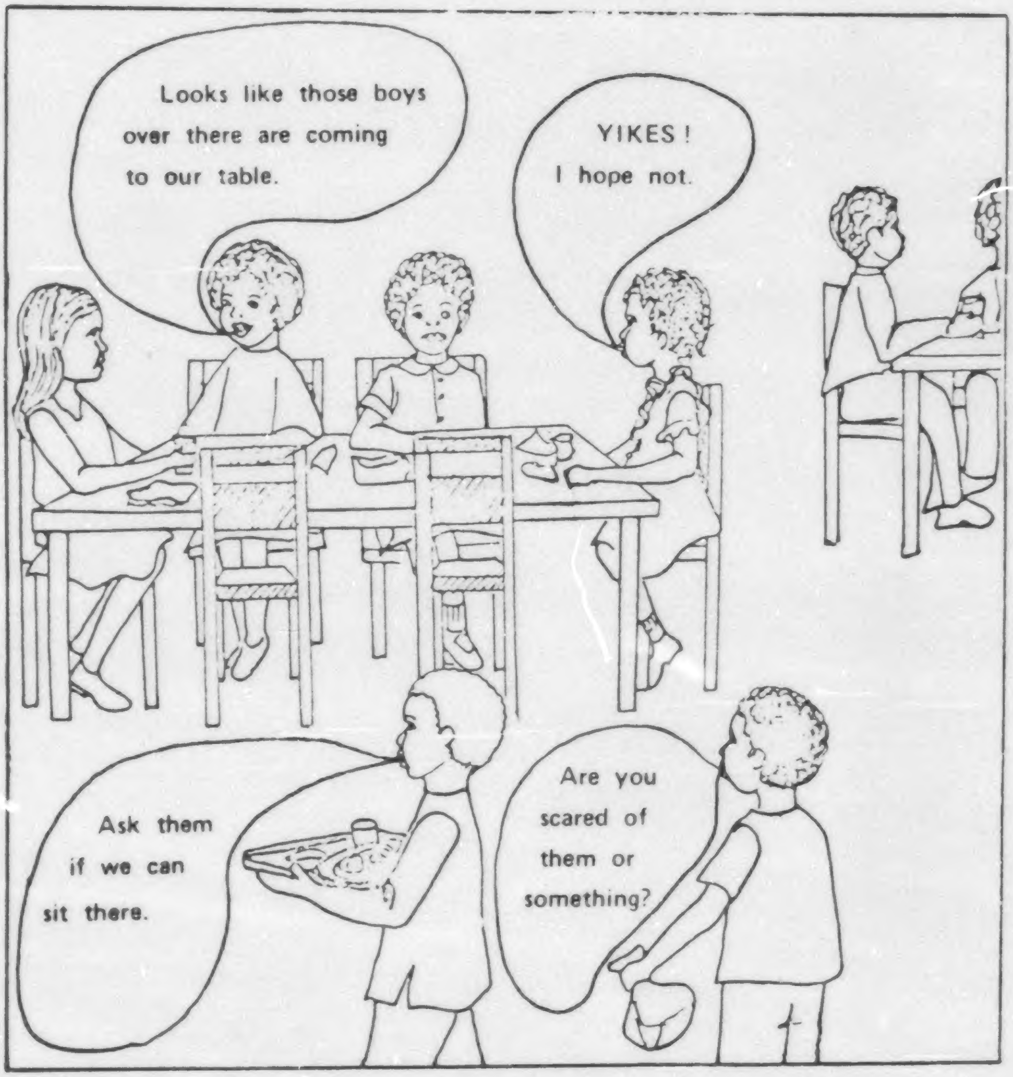
V


Have you heard Michael Jackson's new record?
That Michael's something else.
Hey, do you see any empty seats at a table ?
Yeah, over there with those girls.

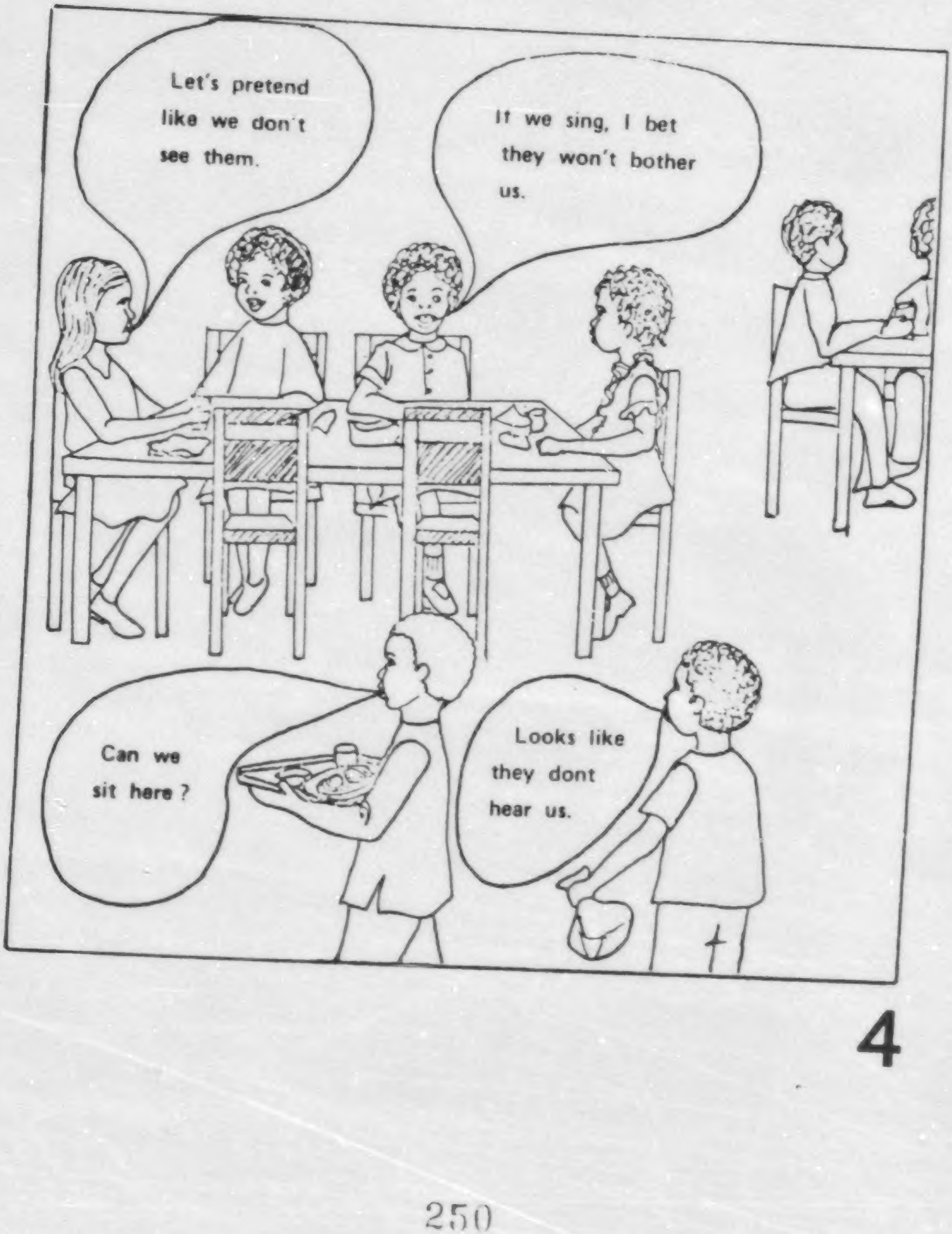
1


I think Germaine's the cutest.
No way, Michael's the cutest.
Don't you just love the way he sings "Ben."
Who wants to sit with a bunch of girls.
Man I'm hungry and I don't care where I sit.

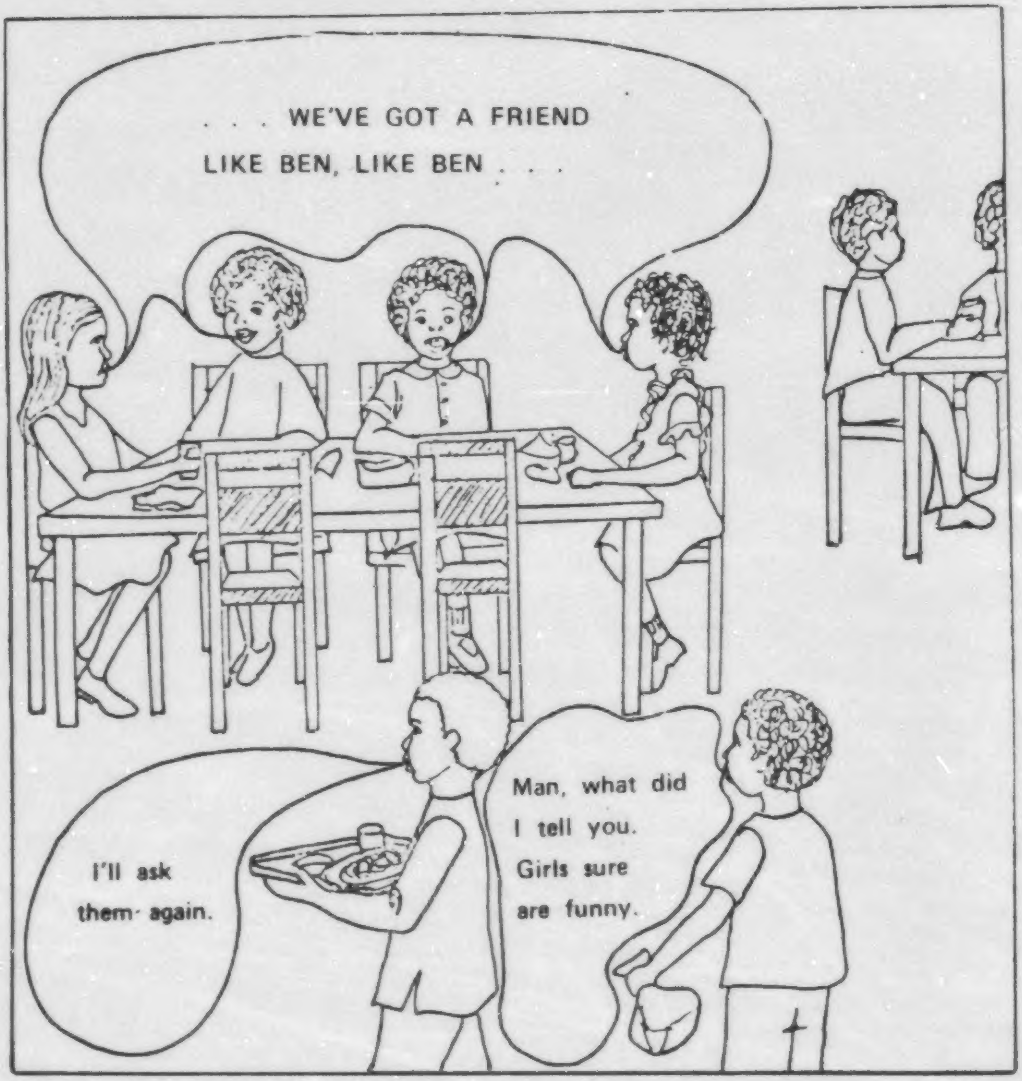
2

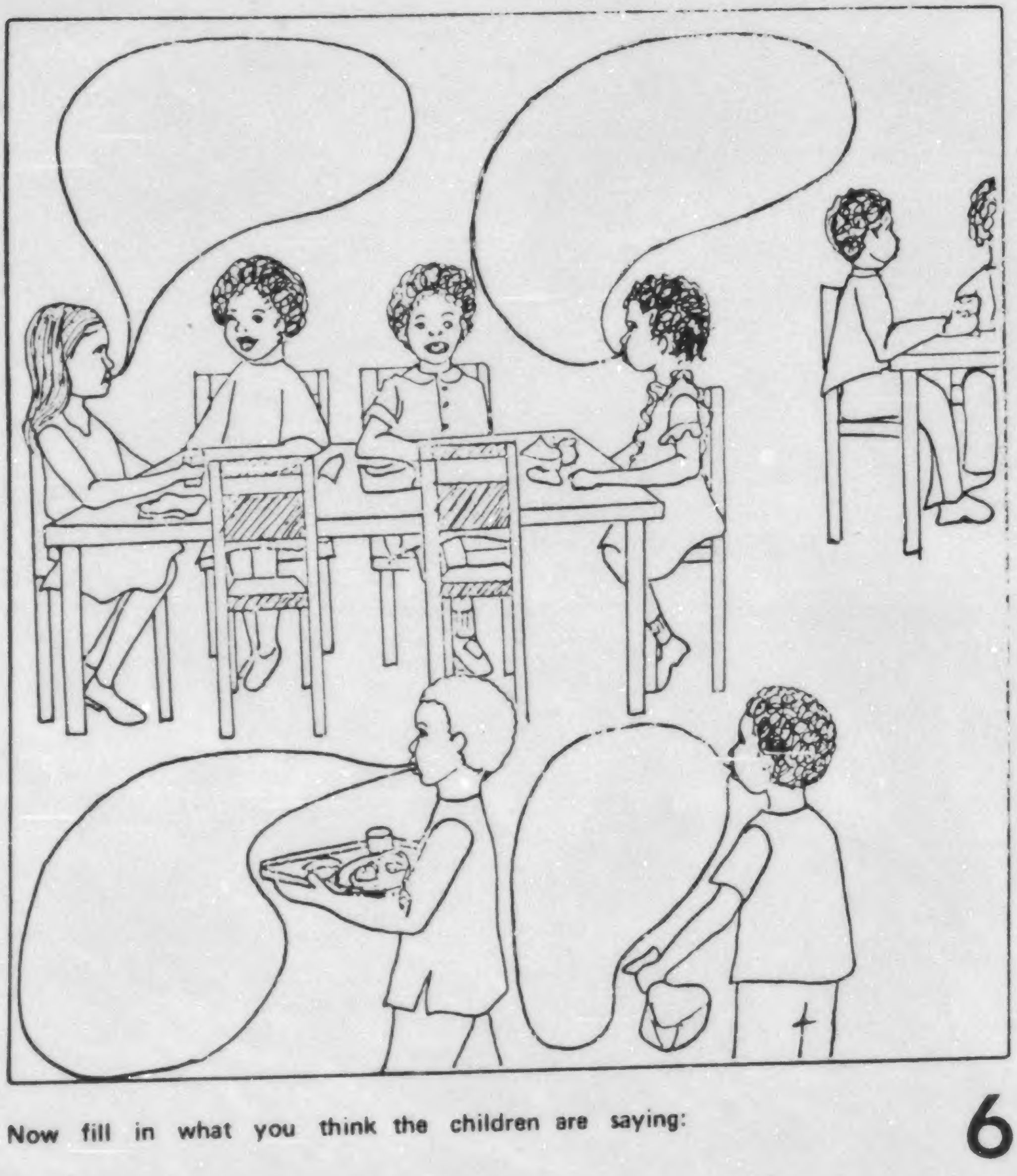

Looks like those boys over there are coming to our table.
YIKES! I hope not.
Ask them if we can sit there.
Are you scared of them or something?

3


Let's pretend like we don't see them.
If we sing, I bet they won't bother us.
Can we sit here?
Looks like they dont hear us.

4


. . . WE'VE GOT A FRIEND
LIKE BEN, LIKE BEN . . .
I'll ask them again.
Man, what did I tell you. Girls sure are funny.

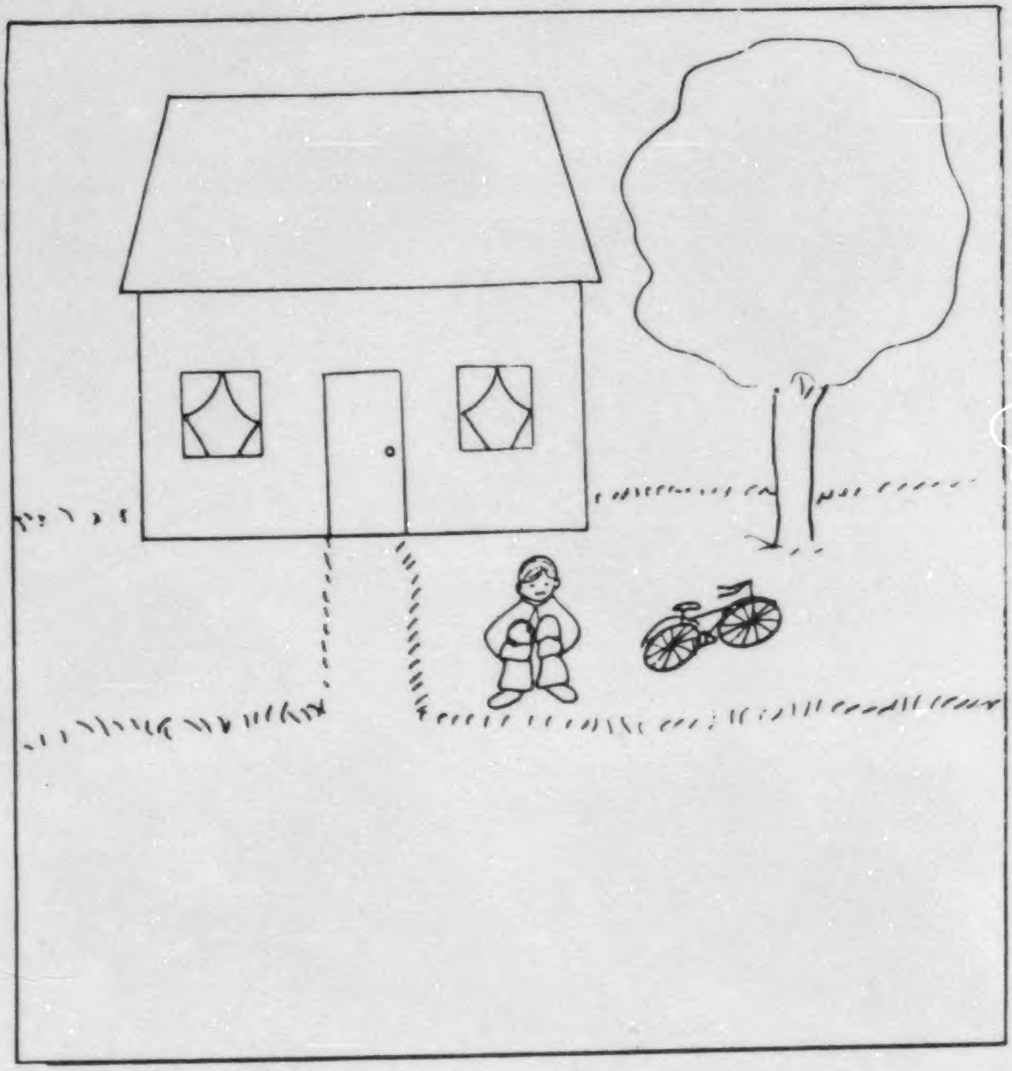


Now fill in what you think the children are saying:

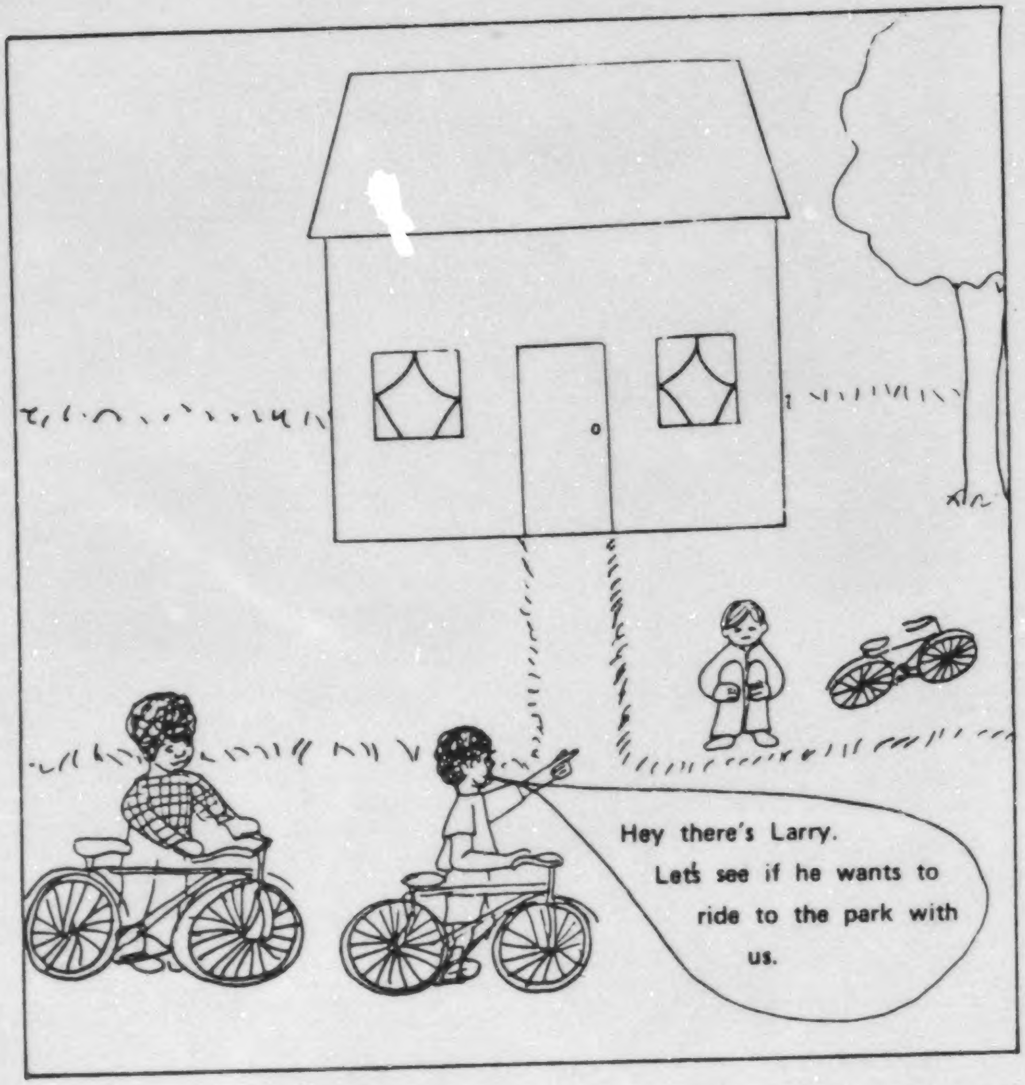
6

" BROKEN WHEELS "

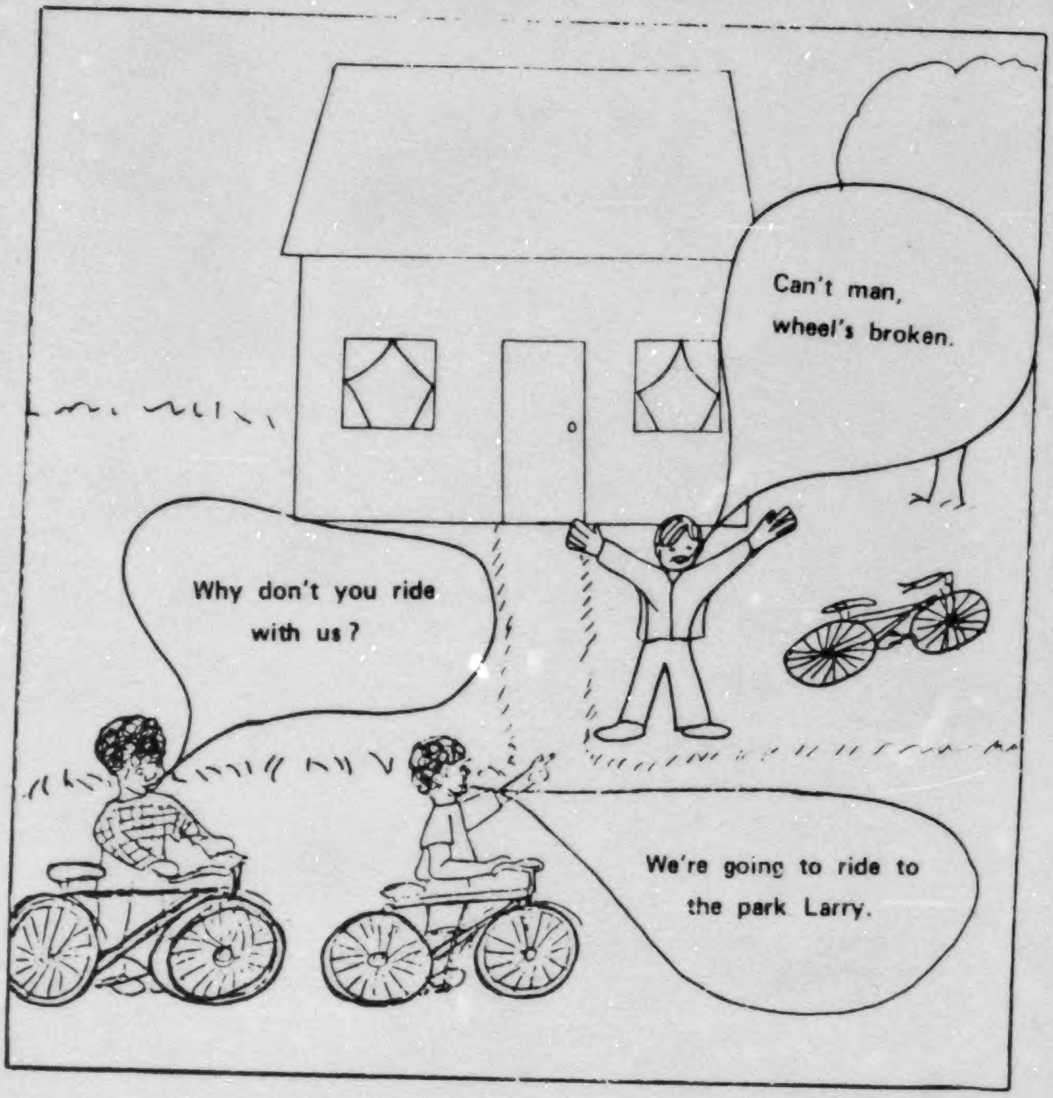
VI



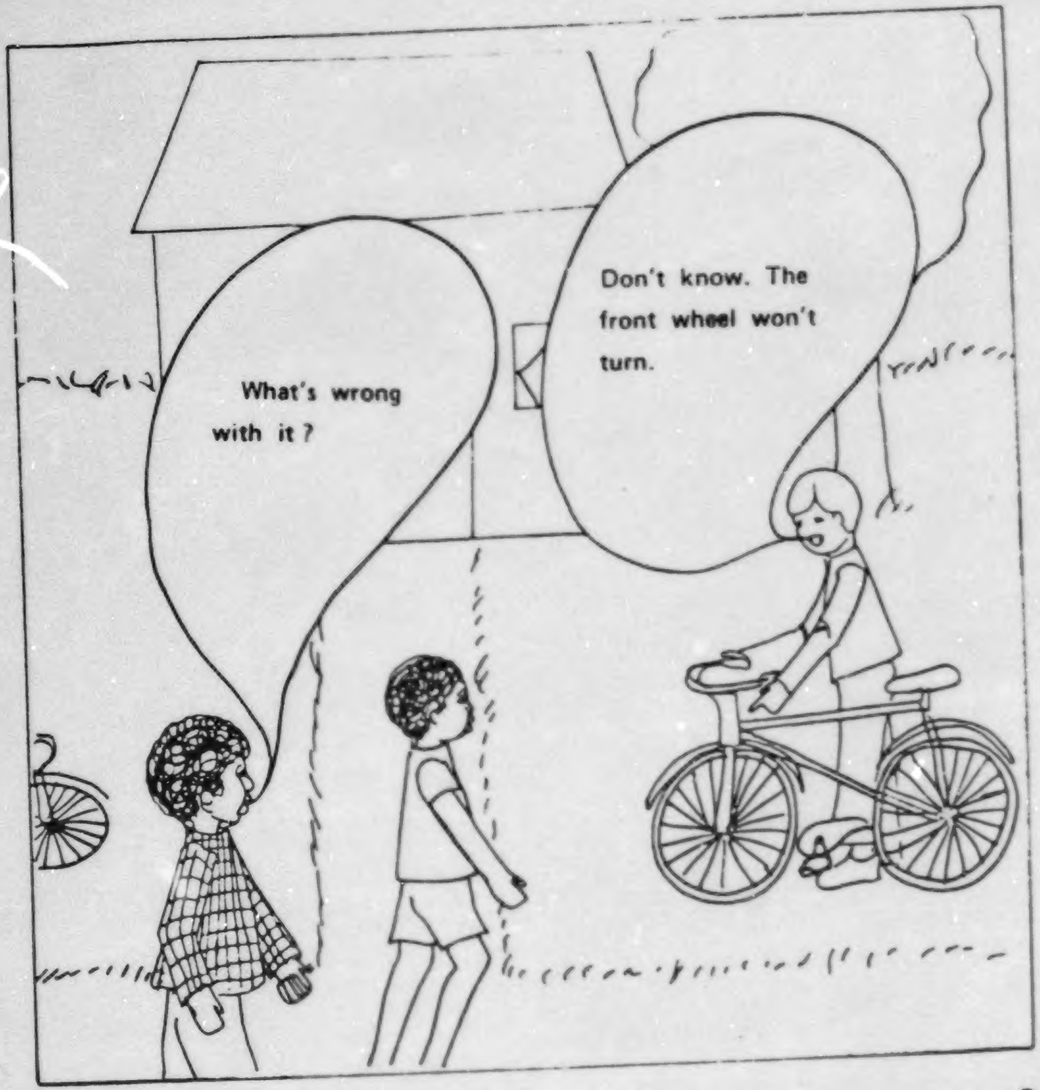
1


Hey there's Larry. Let's see if he wants to ride to the park with us.

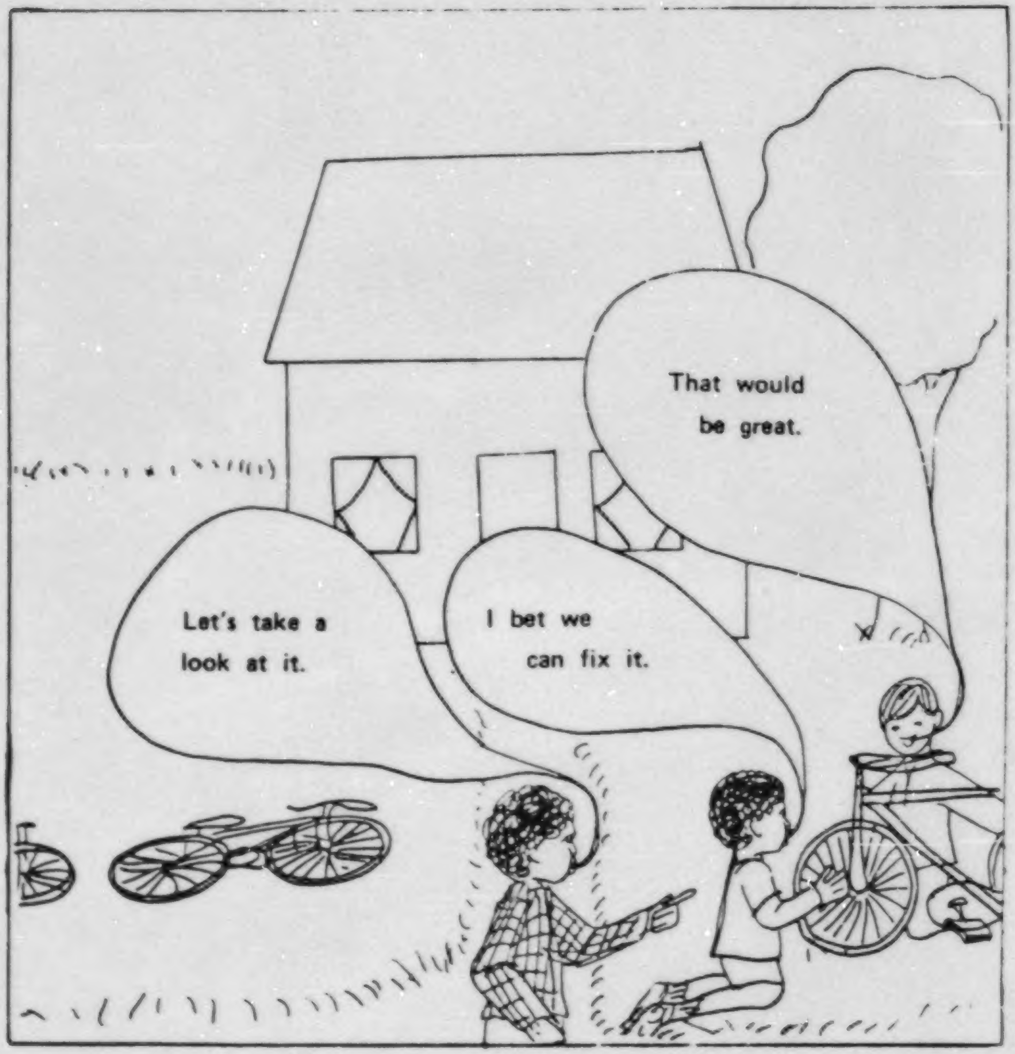
2


Can't man,
wheel's broken.
Why don't you ride
with us?
We're going to ride to
the park Larry.

3


What's wrong with it ?
Don't know. The front wheel won't turn.

4


Let's take a look at it.
I bet we can fix it.
That would be great.

5

Now draw in the picture and fill in what you think happened as well as what the three boys are saying : **6**

Appendix E

Field Test Students and Their Products

STUDENTS AND THEIR PRODUCTS

The impact of the Curriculum Design and Development Training Project can best be judged by its value for the students who study it, the changes it makes in their effectiveness as teachers and the curricula they develop. A brief review of the field study students and their work indicates that the course appeals to a broader spectrum of the population than the graduate education specialist for whom it was designed.

Among the educators have been teachers of elementary subjects, social studies, math, music and fine arts, speech, English, business education, history, physics, earth and space science, guidance, reading, mobility for the blind, and special education. There have been principals, supervisors, school nurses, librarians. A consultant for a national vocational curriculum project task force, a director of biochemical technology, a superviser of employee development, a nursing school director, a college instructor, several community college instructors, a director of business education department of a college, a management systems analyst, several nurses, a practical nurse and a dental hygienist have taken the course. Several graduate students in Educational Communications or other fields of education from the University of Pittsburgh and other universities have been advised to take the course and one student from a State University is getting special permission to use it for the last six credits, for her doctorate although they usually must be taken on the home campus, since there is nothing comparable offered at her school.

Most of the field test students have been hard-working and very highly motivated by particular problems in their job situation demanding the skills the course teaches. Their average age is 35. Several have had doctorates, but on the other hand, one now enrolled does not have a bachelor's degree. Most students have some graduate credits. The problem which motivated one high school guidance counsellor to sign up for the course was rather unusual. There was so much demand for it, she wanted to design a sex education course--for parents!

The following are some of the courses these students have developed or are currently developing:

A community college course for students who need algebra for a degree but have a weak math background.

Development of an entire curriculum for an alternate school for high school dropouts (by the Director).

A liberal arts physics course with no math (sound, optics, electricity, heat, mechanics, etc.)

High school oral communications.

A combination of typing and remedial English for community college students.

Personal development for secretarial students with emphasis on communication skills.

A short story unit for eighth grade, for learning disabilities students particularly.

A course in navigation for boaters.

History of the Black Man

Writing a Research Paper

Individualization of the student-author's business education texts to meet her revision deadlines.

Fundamentals of writing for New Careers students at a community college.

Training courses for 1,000 professional and supervisory utility company personnel. (Operating Superintendent, Supervisor of Division Accounting, etc.)

Individualized course in nursing history.

Basic course in use of library.

Mobility training for the blind.

Most of these students will have impact on education beyond the courses they develop. One, for instance, has addressed the National Business Educator's Association on the curriculum model, one has conducted in-service courses in objective writing in her school. One student has worked with parochial school teachers. One has spoken before a national association of teachers of the blind. Several students are serving on curriculum committees. One student is taking the entire course at a very accelerated rate in order to assist in the changeover of all courses in her Junior College to a competency base.

The students who took part in the field tests of the Curriculum Design and Development Project course have most effectively demonstrated the need, the value, the effectiveness and the impact of the model, the format and the total curriculum package.

Appendix F

Status of Reprint Permission Requests

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"Instrumentation of Bloom's and Krathwohl's Taxonomies for the Writing of Educational Objectives"

Lauren B. Resnick
"Issues in the Study of Learning Hierarchies"

Carl R. Rogers
The "Experiment"

Judy A. Light and Larry J. Reynolds
"Debugging Produce Testing Errors: Procedures for the Formative Evaluation of an Individualized Mathematics Curriculum"

C.M. Lindvall and John O. Bolvin
Programmed Instruction in the Schools: An Application of Programming Principles in "Individually Prescribed Instruction"

Robert Glaser
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C.M. Lindvall
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A.J. Nitko and M. Swanson
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Anthony J. Nitko
"Criterion-Referenced Testing in the Context of Instruction"

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Robert Glaser
"Learning"

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C.M. Lindvall and John O. Bolvin
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